WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

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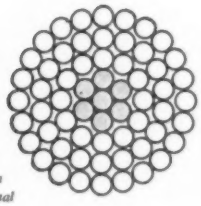
2,100 miles of 61-strand BICC conductor for Super-Grid

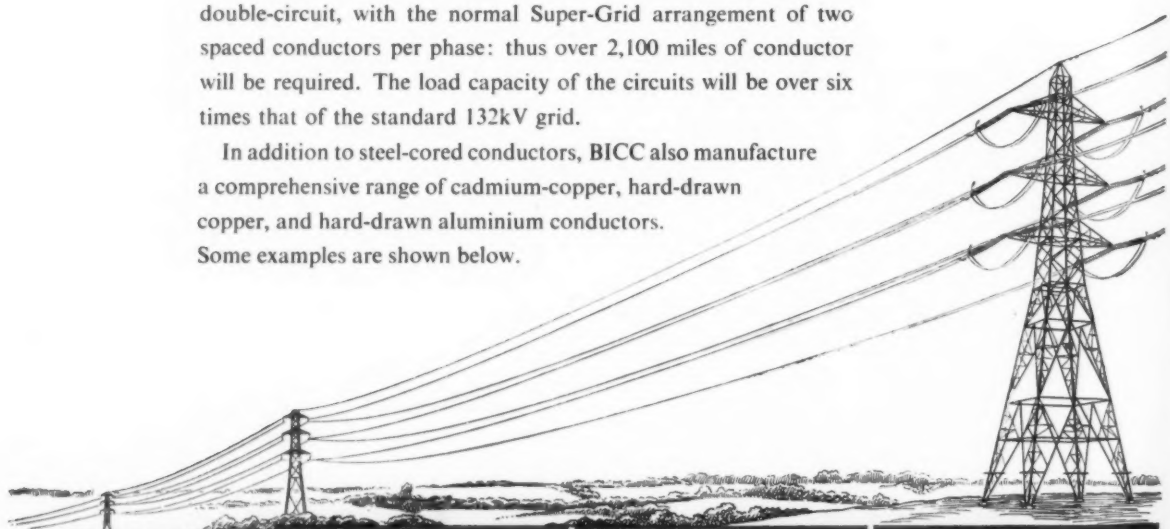


61-strand steel-cored aluminium conductor. Actual size

The BICC Group are erecting 260 miles of 275kV Super-Grid for the B.E.A. One hundred and seventy seven miles of this will be equipped with BICC 61-strand steel-cored aluminium conductor which has an overall diameter of 1.125 inches.

The sections of the route on which it is to be employed are double-circuit, with the normal Super-Grid arrangement of two spaced conductors per phase: thus over 2,100 miles of conductor will be required. The load capacity of the circuits will be over six times that of the standard 132kV grid.

In addition to steel-cored conductors, BICC also manufacture a comprehensive range of cadmium-copper, hard-drawn copper, and hard-drawn aluminium conductors. Some examples are shown below.



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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Further Aspects of Alternative Power

IF evidence were wanting as to the importance attached by power-supply engineers throughout the world to the question of correlating hydro and thermal power, it could be found in the correspondence we received in connection with the editorial "Alternative-Power Economics" which we published in our October 1954 issue. Most of this correspondence was congratulatory—although we did receive one letter of criticism—and derived from engineers in high positions to whom this problem was of immediate practical concern.

As might be expected, the correspondence yielded some interesting items of information and revealed some further aspects of the problem. For instance, we learn that in the Columbia River basin, which has a very large potential of relatively cheap hydro-electric power, preliminary studies have indicated that a combination of hydro and steam power may possibly be a cheaper source of power than some of the hydro projects at present proposed for construction. This is an admirable illustration of the contention in our previous editorial that "it is possible so to interweave the differing characteristics of the two forms of power that the combination offers a degree of availability and overall economy unobtainable from either source separately." This type of consideration was thoroughly discussed in the paper by Haldane and Blackstone, summarised in this journal last month,* which, amongst many other points, brought out the high value of low-load factor hydro-electric plants in taking the peak loads on a predominantly thermal system.

We received some particularly interesting comments from Mr. A. J. Ackerman, an American consulting engineer who has been intimately concerned with the development of power supply in Brazil, and who was present at the Sectional Meeting of the World Power Conference at Rio de Janeiro last summer. Mr. Ackerman was the author of one of the papers presented to the Conference,† and in his contribution to the group discussion on the papers on combined hydro and thermal operation, advanced some considerations which, although relating specifically to conditions in Brazil, are of more than ordinary interest.

The value of Mr. Ackerman's contribution lay primarily in his analysis of the impact of financial considerations on the planning of a combined system, for he was able to show that financial stringency might not merely hamper development but, unless wisely handled, might actually favour the growth of the wrong type of system.

Mr. Ackerman contrasted the situation in the United States, which have immense hydro-electric potentialities, a wealth of coal, oil and natural gas, and ample capital resources, with that of Brazil, which has great resources of water power but is financially restricted and has no abundant indigenous fuel supply except wood. Coal is limited and of very poor quality, and petroleum resources are mostly unknown or undeveloped. Fuel for thermal stations, therefore, has to be imported against foreign exchange, and the fullest development of the country's hydro-electric resources is the obvious line of progress. As Mr. Ackerman stated in his paper, "The annual payments for imported fuel oil consumed in a steam plant (operating at a high load factor) would be equal to the annual charges on a loan to finance the importation of all equipment for a hydro-electric development with a generating capacity six to eight times greater than the capacity of the steam plant."

On the other hand, to quote from Mr. Ackerman's contribution to the discussion, "Once the decision has been made to build a thermal peaking plant, its construction can only be undertaken if a suitable adjustment in the rate structure is made to compensate for the increased cost of operating such special generating facilities for very limited periods of time. The choice of method in adjusting the charges to consumers plays a vital part, thereafter, in determining the course of progressive development of a power system along the best and most economical lines. Depending on the formula used for rate adjustments, an incentive might

* "Problems of Hydro-Electric Design in Mixed Thermal and Hydro Systems." WATER POWER, February 1955, page 68.
† "Planning of the Electric Power Industry in Brazil." By Adolph J. Ackerman, Consulting Engineer, Madison, Wisconsin, U.S.A.

develop to favour thermal generating capacity, operating at high annual capacity factors and, conversely, to encourage the conservation of the hydraulic resources, in spite of the fact that they may be abundantly available. This would be the case, for example, where 100 per cent. of the cost of the fuel consumed in a thermal plant is added as a surcharge to the established rates for a hydro-electric system. Where the importation of fuel demands the diversion of precious foreign exchange, which is already in short supply, the financial position of a country could by this means become very adversely affected over a period of years."

And again, "It has been stated that a thermal plant can be erected at less capital cost. This fact, plus a lack of capital, due to inadequate rates, tends to divert the development of additional generating capacity into a direction which provides the lowest first cost of installation by means of a thermal plant. When, in addition, an automatic surcharge on established rates is requested and authorised, which provides for 100 per cent. reimbursement of fuel costs, there is a danger that this type of system expansion may grow, notwithstanding the fact that such operation of thermal plants (involving the continuing consumption of imported fuel), places an additional burden on the country's already limited financial resources which are needed for the payment of other imported necessities. The protection of the national interest in such matters calls for farsighted planning on the part of all who have a share in this responsibility. For a hydro-electric project, the hydrology, land acquisition and governmental concessions generally require the preliminary work to begin two to three years earlier than is needed for a thermal plant. Where such preliminaries have been neglected, the resulting power shortage may create a public clamour for the quickest possible solution, and for this a thermal plant presents a tempting answer, since its harmful effect on the country's credit position may then be claimed, in some quarters, to be a less serious prospect than the consequences of a power shortage. The heart of the problem, therefore, lies in the wisdom and perseverance which is exercised in the preliminary planning stage of a hydro-electric project."

These remarks will surely provide food for thought in other countries than Brazil.

Symposium on Observation of Structures

THIS symposium will take place under the aegis of Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, during the week commencing October 24, 1955, and will be concerned with the measurement techniques used for the observation of structures of various types, notably storage dams for hydro-electric schemes, bridges and buildings. Among the subjects to be discussed will be the characteristics of the different instruments used for measuring displacements, strains, stresses, velocities, joint movement, temperatures, pore pressures, humidity and the propagation of vibrations. The methods of using these instruments will also come under review together with the determination of the mechanical properties of the steel, concrete, soils, etc., to which they are applied. Other sections of the symposium will deal with the determination of loads on a structure due to wind, earthquake forces, earth pressure, etc., and with the planning of a complete installation of instruments for structures of different kinds. The analysis and interpretation of the date obtained from these installations will also be discussed.

Engineers wishing to take part in the symposium should write to the Laboratório Nacional de Engenharia Civil, Avenida do Brazil, Lisbon, Portugal.

North American Resources

IN his budget message to Congress last month President Eisennower referred to the policy of the United States Government in encouraging the development of long-range projects, particularly those that could be shared by the State and other legislatures. For example, the State of New York and the Province of Ontario were now jointly developing the power resources of the St. Lawrence river without cost to the Federal Government. Under legislation passed last year the Markham Ferry project in Oklahoma and the Priest Rapids project in the State of Washington, both with large power developments, would be built by State or local units, with modest Federal contributions only for those purposes such as flood control which involved national responsibilites. The Budget proposed the initiation of several new construction projects under such partnership arangements, and by these means, the President added, natural resources were being developed at less cost to the Federal Government.

Paulo Afonso Project, Brazil

PRESIDENT Joao Cafe Filho recently dedicated the 180,000 kW Paulo Afonso hydro-electric project, the largest postwar power development in Brazil. This new underground power station is situated on the Sao Francisco river and will supply low-cost electrical power to parts of five north-eastern states. It is the first of five such plants which are to be developed and operated by Companhia Hidro Electrica do Sao Francisco in exploiting the large power potential of Paulo Afonso falls. All the electric generating equipment, as well as the equipment for the operation of two high-voltage transmission lines extending to the coastal cities of Salvador and Recife, each approximately 250 miles away, was supplied by an American firm, the Westinghouse Electric International Company.

New Zealand's Power Supplies

ACCORDING to a statement by Sir John Hacking, New Zealand will have to double the present rate of power production by 1966 if supply is to keep pace with demand. This warning has increased misgivings throughout the country about a possible return to restrictions on the use of power, a factor which hampered national development until late in 1953. The new power stations being built cannot hope to cope with the demand expected in 1958 and 1959 but shortage of labour has hampered progress.

The North Island, with double the population of the South Island, is rapidly approaching maximum use of its water resources for power production, and is expected to suffer most when the crisis, anticipated in 1958, arises. The South Island will by then be drawing on the 320.000 kW Roxburgh project now being built on the Clutha river.

The North Island, now in a stage of great industrial expansion, hopes that two new developments will ultimately lead to a solution of its electricity difficulties. The first of these is the use of geothermal steam for driving turbines. Boring at Wairakei has proved sufficient steam for the operation of a station having a capacity of 40,000 kW which will be used for the production of heavy water. Plant is being designed in Britain and building is expected to begin within a year. The British Government is sharing the cost as it will use the heavy water for atomic development.

Pumped-Storage Scheme for Wales

MERIONETH County Council have decided to rescind a previous resolution opposing the North Wales Hydro-Electric Bill for a £15m. pumped-storage scheme at Tan-y-Grisiau, Blaenau Festiniog, and which they at first considered would destroy the amenities of the district.

This decision was taken after Councillor C. M. Jones had submitted the report of a committee which had examined the matter and recommended that no objection be made to the scheme in view of assurances given on several points by the British Electricity Authority.

Instrument Exhibition

THE third British Instrument Industries' Exhibition to be held at Earls Court, London, from June 28 to July 9, 1955, will be the largest of its kind. It will show the latest equipment of manufacturers of scientific and electrical instruments, industrial meters and automatic controls. Instrumentation and controls are important to every industry by providing means for research and for establishing and maintaining optimum working conditions, thereby securing increased and cheaper production. Experienced technologists will be available throughout the exhibition to demonstrate the many ways in which equipment can be used. The organisers, F. W. Bridges and Sons Limited, have made arrangements to cater for the needs of overseas visitors, and it is already apparent that large numbers will be attending.

The exhibition is sponsored and actively supported by The British Electrical & Allied Manufacturers' Association; The British Industrial Measuring & Control Apparatus Manufacturers' Association; The British Lampblown Scientific Glassware Manufacturers' Association; The Drawing Office Material Manufacturers' & Dealers' Association; and The Scientific Instrument Manufacturers' Association of Great Britain.

St. Lawrence Turbines

THE Power Authority of the State of New York has announced approval of the award of a contract for eight hydraulic turbines for the St. Lawrence Power Project to Allis-Chalmers Manufacturing Company. According to Robert Moses, chairman of the Power Authority, the contract totals $5,051,461. The turbines will be installed in the Barnhart Island power house of the project located in the St. Lawrence about five miles from Massena, N.Y.

Each of the turbines will be rated 79,000 h.p., 94.7 r.p.m. at 81 ft. head. The propeller-type fixed blade runners will be of cast steel and the scroll case will be concrete. At the point of best efficiency each unit will develop 71,000 h.p. Turbines will incorporate the lastest improvements in design, including automatic grease-lubrication systems.

Model tests are already under way at the manufacturer's works and delivery is scheduled to begin in June 1956 and to extend to January 1959. Over 400,000 man-hours will be required in the building of these turbines.

Loch Glashan Scheme

THE North of Scotland Hydro-Electric Board announce details of their Loch Glashan hydro-electric scheme (Constructional Scheme No. 71) which will produce 17,600,000 kWh annually. The scheme provides for utilising the waters of Loch Glashan, which lies north-east of Lochgilphead among the hills behind the hamlet of Lochgair in the County of Argyll. The natural catchment area of the loch is only four sq. miles but this will be extended by a further 20½ sq. miles by means of diversion aqueducts. All this water will be impounded in a dam, 1,100 ft. long and 45 ft. high, to be built at the outlet of Loch Glashan. From this dam the water will be led by a tunnel and pipeline 5,500 ft. long to a power station with a capacity of 4,200 kW situated on the shores of Loch Gair. The single turbo alternator will operate under a head of 356 ft.

The Loch Glashan scheme is required to help in meeting the rapidly growing demand for electricity in the Kintyre and Knapdale areas but the Board's engineers are already having to consider further reinforcement which may take the form of an extension of the Highland Grid from the Shira scheme, near Inveraray, to Kintyre.

Standard Sizes for Trade Literature

THE British Standards Institution has issued a specification (No. 1311) to cover "Sizes of Manufacturers' Trade and Technical Literature," including recommendations for the contents of catalogues. This standard has been prepared to meet representations from a number of important trade associations, chiefly in the engineering and building industries, and no less than 38 organisations took an active part in the work; it is designed to overcome two main difficulties. Firstly, when large plant is installed, one aspect of the contractor's work is simplified if he can furnish full working instructions to his customer by assembling into one binder all the working instruction sheets issued by sub-contractors and suppliers of ancillary equipment.

Secondly, with catalogues, brochures and pamphlets similar considerations arise. The psychological aspect of this is particularly important for exports because sizes of literature have been standardised in many countries for years. In addition, even if there is no question of grouping with other publications, a great variety of shapes and sizes can become a considerable nuisance to librarians and others who wish to retain literature for reference.

Copies of this revised British Standard are obtainable from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1. Price 2s. 6d.

The Sog Development

Steingrimur Jonsson, Electrical Engineer Director of Sog Power Company, Reykjavik, describes Iceland's newest station at Irafoss.

THE river Sog in the south-western part of Iceland has its origin in lake Thingvallavatn, which with an area of 33 sq. m. is situated 336 ft. above sea level. From the lake the river runs through a gorge to a smaller lake, Ulfljótsvatn, situated 264 ft. above sea level. Below this stretch there are three waterfalls, Sogsfossar, in a distance of only a few miles. The total head of these falls is 179 ft., and from the last, which brings the river down to 85 ft. above sea level, the waters gradually descend towards the Atlantic Ocean.

The total head that is available in the Sog is thus 251 ft., and this will be utilised in three separate power plants. The uppermost, at the gorge, is the Efra-Sog station and utilises a head of 72 ft.; the Ljósafoss station at the outlet of the lower lake utilises a head of 55 ft., while the Irafoss station harnesses the two lowermost falls which have a total head of 124 ft.

The drainage area is about 320 sq. miles, while the average dis-

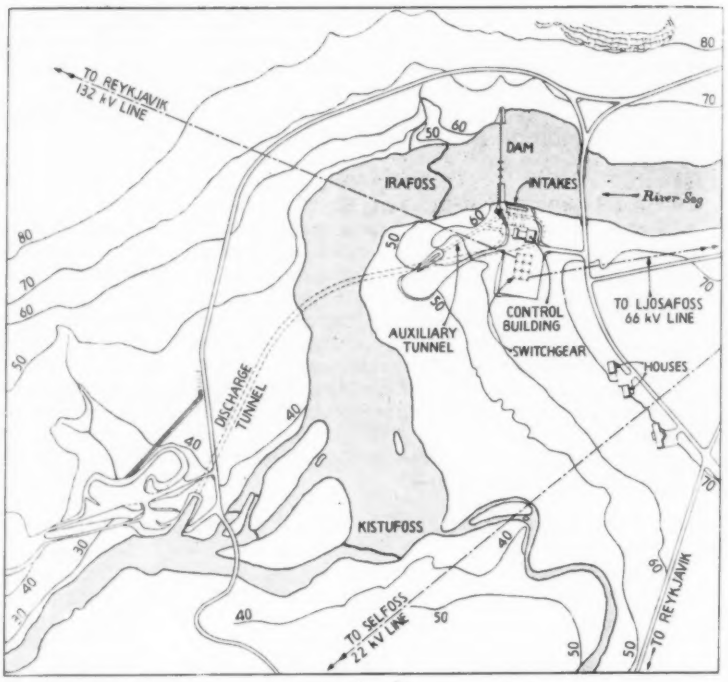


Fig. 1. Sketch map of Irafoss power scheme

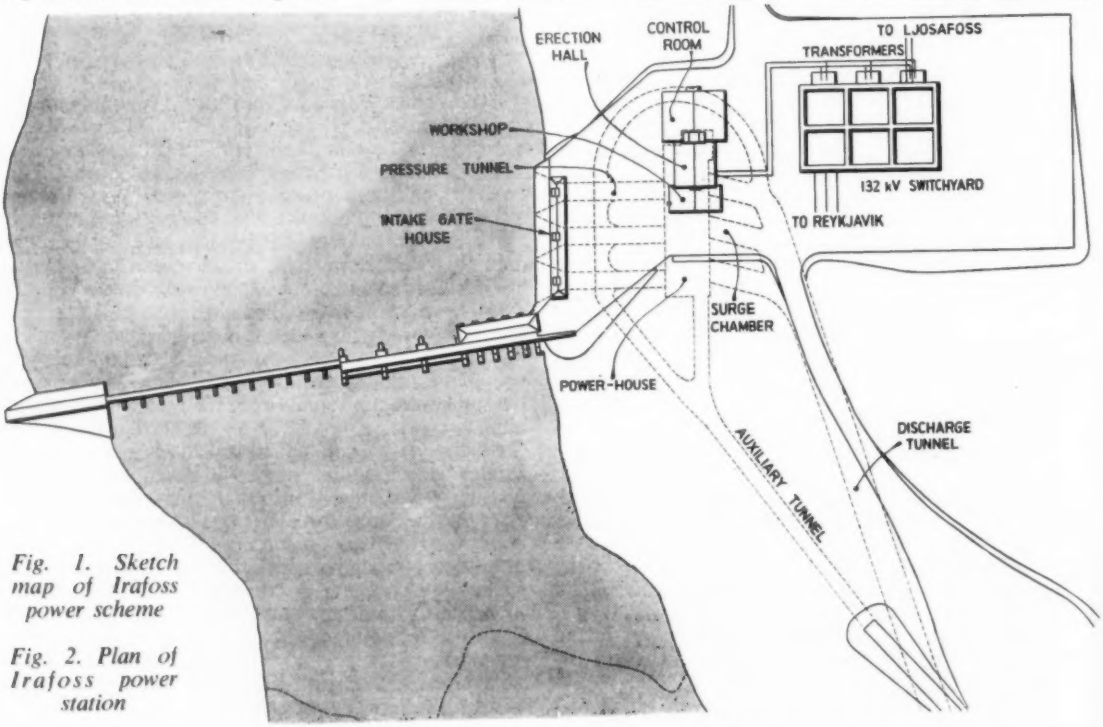


Fig. 2. Plan of Irafoss power station

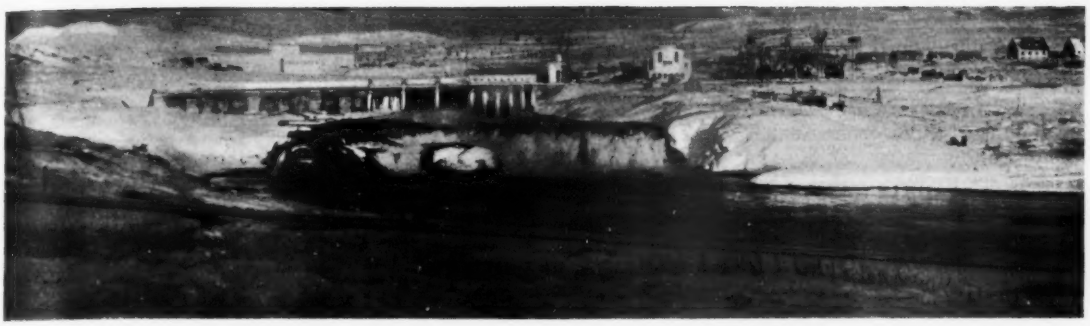


Fig. 3. Irafoss plant with Ljósafoss plant in background and Irafoss waterfall in front

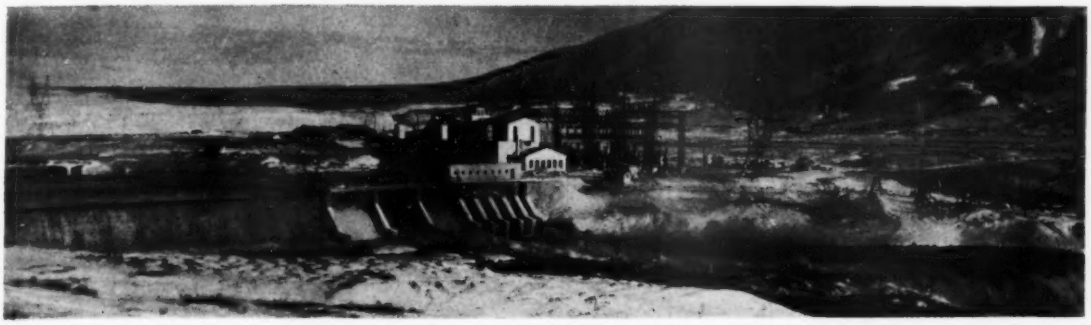


Fig. 4. Further view of Irafoss plant

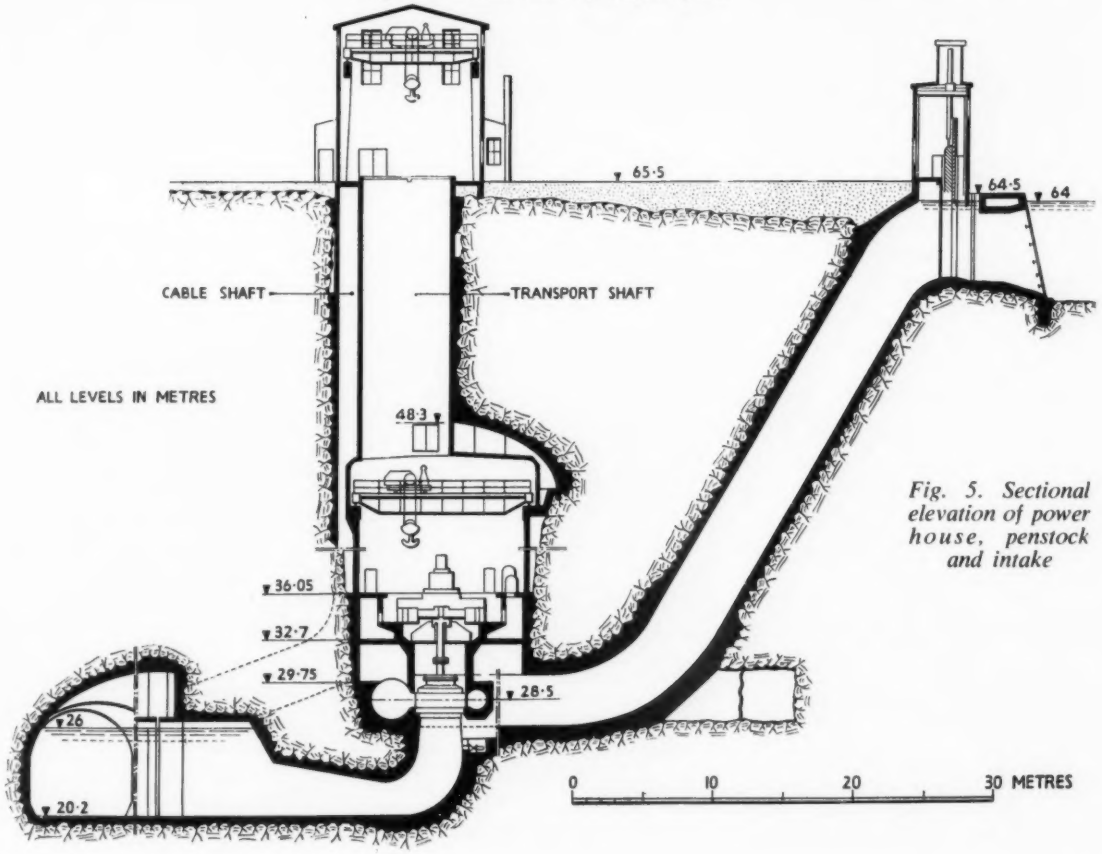


Fig. 5. Sectional elevation of power house, penstock and intake

charge of the river is 4,000 cusecs. The flow throughout the year is exceptionally uniform, the minimum measured flow being 75 per cent. of the average and the maximum 150 per cent. Annual production is based on 80 per cent. of the average flow and the maximum output of all three stations is calculated on a flow of 5,200 cusecs taking advantage of the possibility that exists of regulating the lakes.

The Ljósafoss station was erected between 1935-37 and comprises two units with a capacity of 4·4 MW each. In 1944 a third unit of 5·5 MW was put into operation, and since then the station has operated continuously with a maximum capacity of 16 MW and an annual production of about 100 million kWh.

Irafoss station, the one with which we are concerned in this article, was built in the years 1950-53. In the first stage only two of three possible units were erected, each with a capacity of 15·5 MW. The ultimate capacity of the station will be 46·5 MW and it will have an annual production of 240 million kWh.

The Irafoss plant

The Irafoss power plant is an underground station, the first of this type to be built in volcanic Iceland. The dam, of the Ambursen type, is situated above the Irafoss fall, and has a total length

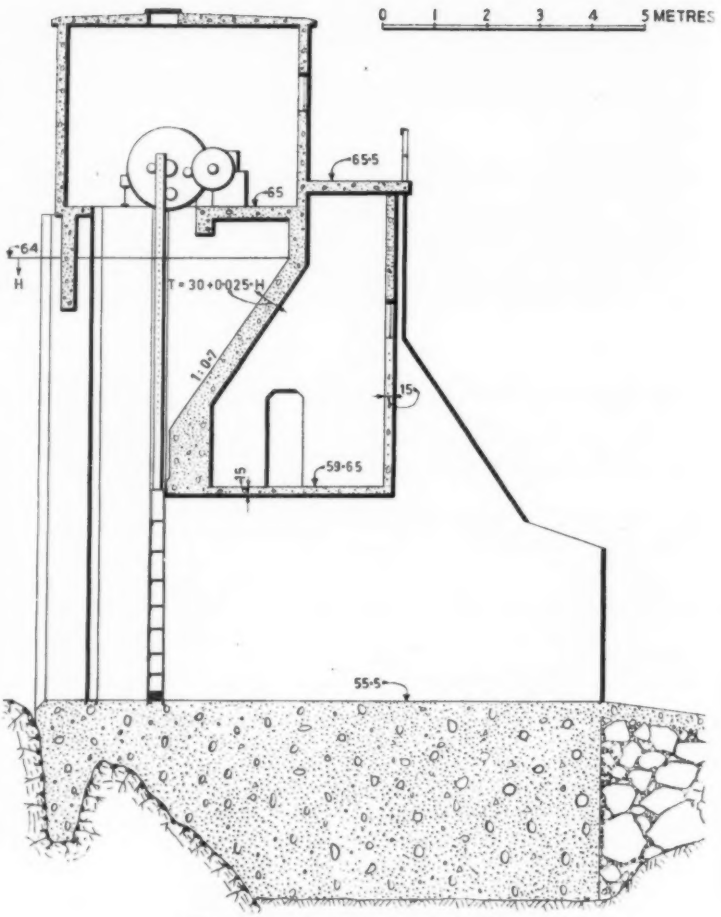


Fig. 6. Section bottom sluice gate

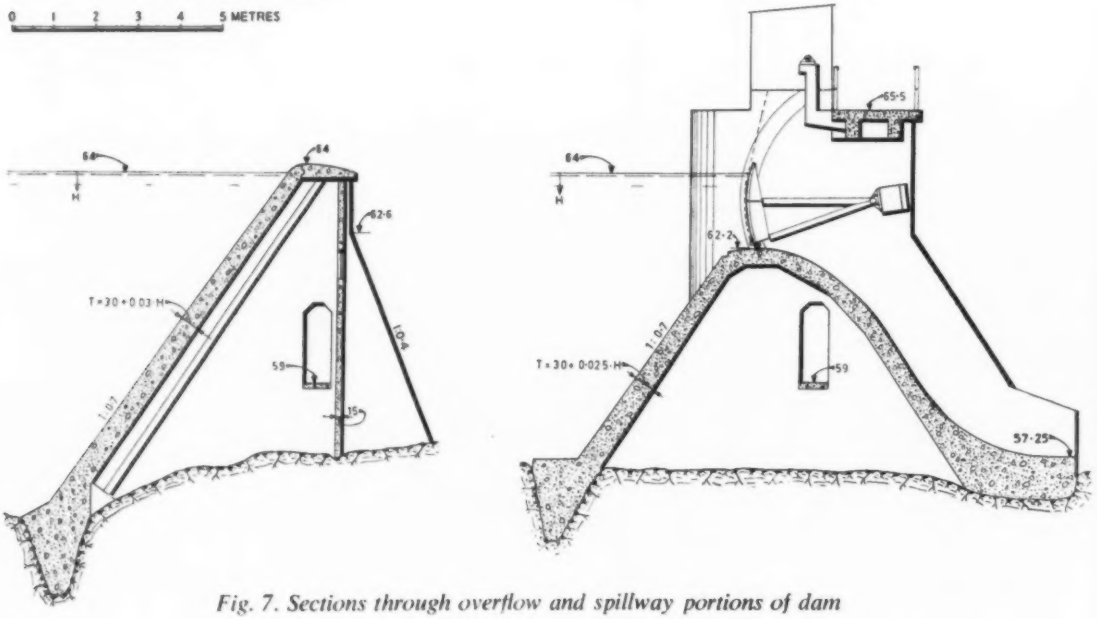


Fig. 7. Sections through overflow and spillway portions of dam

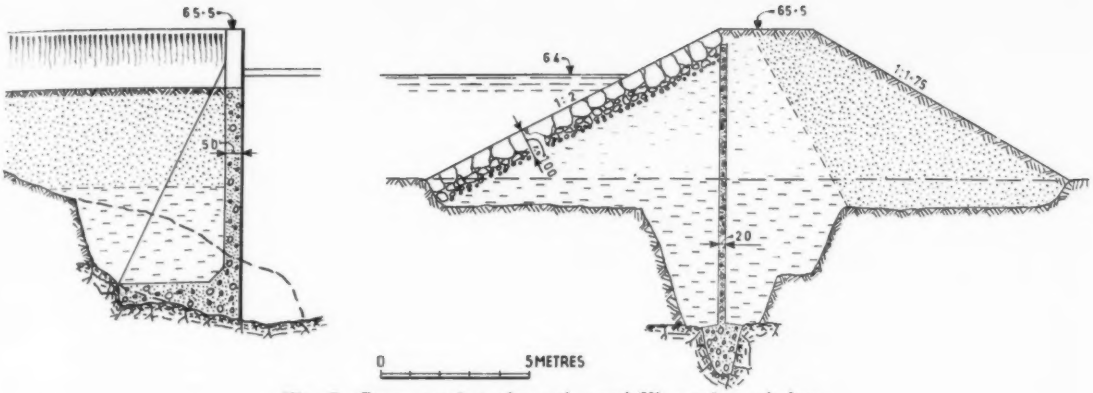


Fig. 8. Cross section through earthfill portion of dam

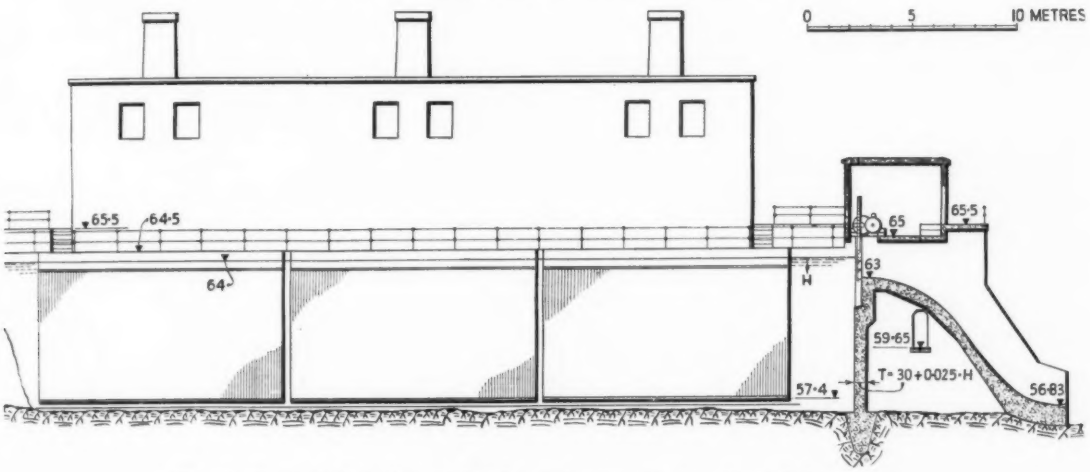


Fig. 9. Frontal elevation of intake and cross section through ice sluice

Fig. 10. Dam during latter part of constructional period

of 540 ft. and a maximum height of 43 ft. It raises the water level to 209 ft. above sea level, i.e., the same height as the tailrace of Ljósafoss station. There are three tainter gates $6 \times 32{\cdot}5$ ft., three bottom sluices 13×10 ft., an ice sluice and a free overflow spillway having a length of 225 ft.

The intake on the east bank is placed almost at right angles to the dam axis. There are three openings, screened by electrically heated racks. Each opening is dimensioned for a flow of 1,720 cusecs, and leads the water to one of three circular pressure penstocks, sloping at 60°, and having an inside diameter of 16 ft. 6 in. They are lined with reinforced concrete in the solid rock and are steel lined at the lower ends, where they are connected to the spiral casings of the turbines.

After leaving the draught tubes the water passes into the surge chamber cut out of the rock and

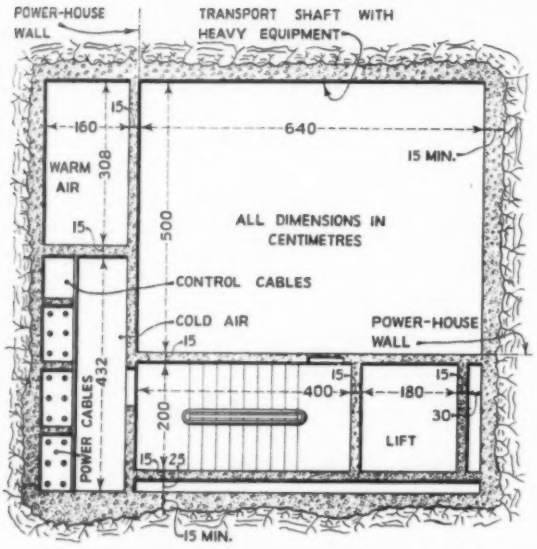


Fig. 11. Section through vertical access shaft

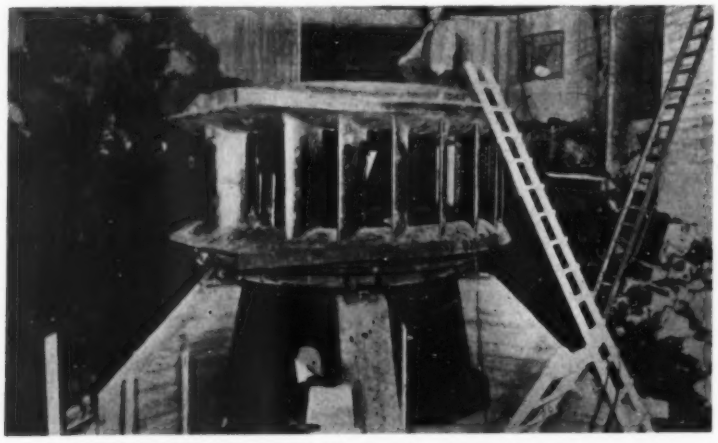


Fig. 12. Erecting turbine suction ring and stay ring

then flows into a free-level tailrace tunnel. Both the surge chamber and the tunnel are lined with concrete. The length of the tunnel is 2,100 ft., and it has a cross sectional area of 550 sq. ft. From the tunnel the water flows in an open channel, 260 ft. long, back to the river.

The power house floor lies 93 ft. under the surface, and is 137 ft. long and 40 ft. in width. It is lined throughout with concrete, the lining being self-supporting with a space between the rock and the walls. A travelling crane of 75 metric ton capacity traverses the length of this chamber. A reinforced-concrete vault supports the rock, and the false roof, consisting of 3 in. of concrete, is suspended underneath.

At the northern end of the powerhouse there is a vertical shaft which leads up to the switchgear chamber and control room. Besides serving for transport, the shaft is provided with an elevator, a staircase, conduits for cables, and also has a ventilation duct which connects with the surge chamber by means of a short tunnel. This tunnel affords a convenient means of compensating the air-pressure variations caused by transient wave formations in the tailrace tunnel when the load changes suddenly. The erection hall, also reached by the vertical shaft, is served by a travelling crane of 40 metric tons capacity.

In this first stage two 22,000 h.p. Francis-type, vertical-shaft turbines, with a speed of 187·5 r.p.m., have been installed. The governors have the oil-pressure servomotors on the turbine floor in the basement, while the actuators are placed in the upper floor. The governors are operated by electric motors supplied either by a separate transformer from the generator mains or by a permanent-magnet generator on the top of the generator shaft.

The generators, placed on the floor above the turbines, are of the umbrella type and are 3 phase 50 cycle machines with an output of 19,375 kVA 0·8 power factor and 10·5 kV. The short-circuit ratio is 1·0. The main exciter and pilot exciter are placed on top of the generator.

The stator is installed in a concrete housing and the upper cover plate of the generator is flush with the floor. Current transformers for the differential protection and earthing equipment for the generator windings are installed on the generator floor, where, also, the generator cables are placed in fibre conduits.

From the 10·5 kV switchgear room the cables are drawn to an outdoor switching and transformer station having a steel-frame superstructure. There the generator voltage is stepped up to 132 kV and transmitted to the capital, Reykjavik, a distance of 32 miles. The station is tied to Ljósafoss through a 15 MVA transformer and a 60 kV line.

The main transmission line is built on steel towers with steel-aluminium cables, arranged horizontally in line and supported by 11 - link suspension - insulator chains. There are no earth wires on top of the towers except for a distance of three miles at each

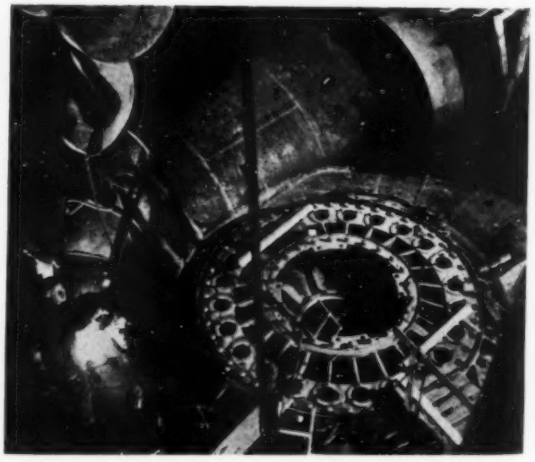


Fig. 13. Interior of power house, showing erection of turbine

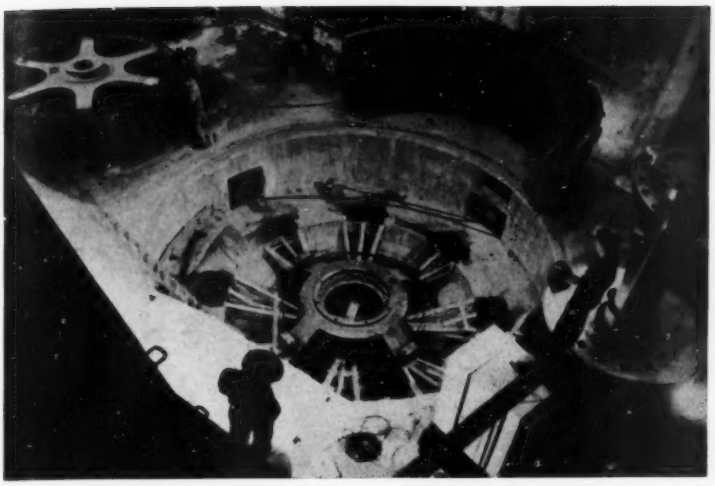


Fig. 14. Generator in course of erection

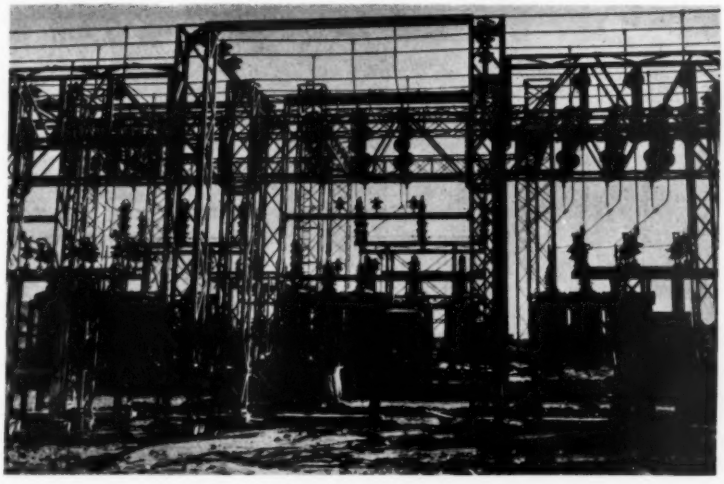


Fig. 15. Outdoor switching station

end of the line. The ultimate carrying capacity of the line is 96 MW, i.e., the full capacity of the river Sog.

The Civil Engineering Works

To facilitate and expedite the rather complicated underground blasting it was decided to drive an auxiliary tunnel making it possible to open on three faces at the same time.

The tailrace tunnel was driven from the lower end to full dimensions (680 sq. ft.). Working in two shifts the rate of advance averaged 10 ft. per working day. Once the work was brought into rhythm it took about 12 months to drive the tunnel.

The drilling was performed with Atlas RH 656 W and 754 W equipment, fitted with pneumatic pushers and operated from a drilling jumbo erected on an old GMC truck. The mucking operation was accomplished by a Koehring 304 excavator, fitted with a shortened boom, while five 5¼ cu. yard capacity Koehring dumpers, type 60, hauled out the muck.

The tunnel passes through basalt lava, palagonite tuff and moraine formations. Drilling in the basalt was ideal, with considerable speeds and very little wear on the drills, but the other formations were rather difficult. Usually, Coromant ⅞ in. drill rods with one bit consisting of a tungsten-carbide insert were used, but on the bad stretches three and four bit drills were put into use and good results were achieved. The ground encountered was of inferior hardness and the drills scarcely needed to be reground, but broke just under the neck as a result of metal fatigue.

No support of the roof was anywhere needed, although the largest span in the basalt lava in the surge chamber was about 50 ft. The tunnel passes under the river with only 46 ft. of rock between the roof and the river bottom. In spite of this the leakage was negligible.

The transport shaft was driven vertically downwards to a depth of 80 ft., the cross section being 120 sq. ft. The blasting for the roof vault of the power house was then blasted out and subsequently concreted in sections as it was considered too great a risk to let

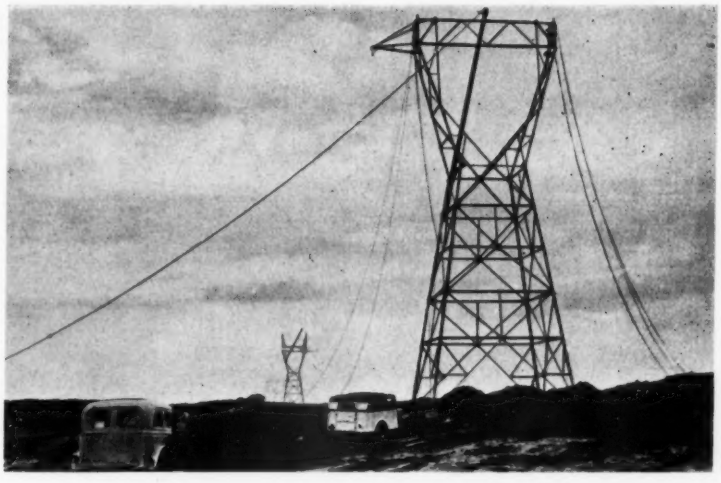


Fig 16. Transmission line tower in lava field

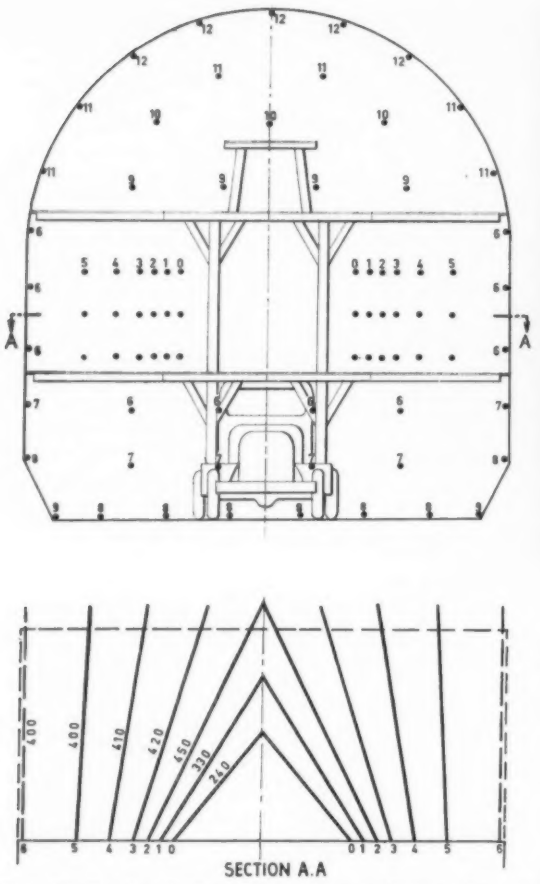


Fig. 17. Sectional elevation and part plan section to show drilling scheme in tailrace tunnel

Fig. 18. Tailrace tunnel after concreting of floor

the palagonit roof support itself to any extent. All the muck had to be hauled up through the shaft. An Eimco 12 B loader was used for loading in the roof area.

The auxiliary tunnel, with an area of 160 sq. ft., was driven into a cliff to the south of the station and at a slope of 1 : 7. It reached the stations just as the concreting of the vault was finished, thus enabling subsequent muck removal to proceed with the help of an excavator and dumpers.

Unhappily, the rather bad rock encountered under the foundation of the vault stopped the excavation work for a while. The walls had to be secured with anchor bolts, at the outer ends of which reinforcing bars were fastened and the whole cemented over.

A branch of the auxiliary tunnel was driven around the station into the surge chamber, and the draught tubes were blasted out before the tailrace tunnel reached this chamber. From this branch also the three penstock tunnels were blasted. A pilot rise 36 sq. ft. was first driven upwards at a 60° slope and divided horizontally by a wooden partition, the under compartment forming a muckway and the upper a manway. When the pilot rise was completed the excavation was enlarged to full size, 19 ft. in diameter.

The total length of the auxiliary tunnels is 750 ft.

Concreting. Special interest is attached to the lining of the tunnel. Excellent results were obtained by a travelling steel shuttering 35 ft. in length and designed and constructed by Mr. C. Parry, of London. The concrete was handled by a compressed-air operated

Fig. 19. Showing arrangements for lining walls and roof, tailrace tunnel

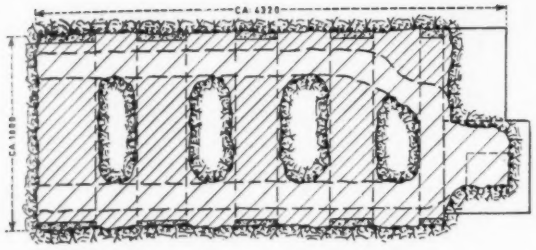


Fig. 20. Plan of excavation under power house vault

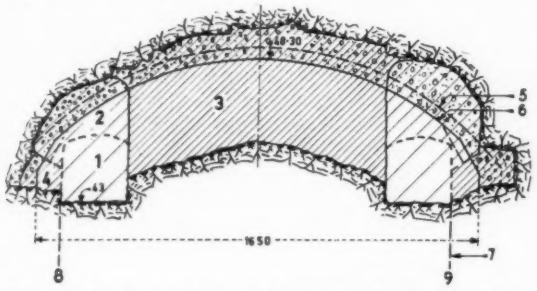


Fig. 21. Section of power house vault showing supporting arch; the numbers indicate the sequence of operations

¾ cu. yard PressWeld placer. It was transported from the batching plant in two 1½ cu. yard agitating cars and delivered in the power house over the third draught tube. This placing was ideal, as the process of concreting could be performed without interference from the weather and the shortest transport distances were involved. The batching plant included two 750 litre Torno mixers, with a capacity of 25 cu. yards, and a maximum output of 35 cu. yards per hour.

Total quantities involved were: shuttering, 460,000 sq. ft.; steel reinforcements, 586 metric tons; concrete, 35,000 cu. yards; excavation by blasting, 125,000 cu. yards; excavation without blasting, 25,000 cu. yards.

Management. The Sog Hydro Electric Power Company is owned partly by the State and partly by the Municipality of Reykjavik. It is managed by a board elected by the owners, the State electing two members and the Municipality three members.

The contract for the civil-engineering work was placed with a Danish and Scandinavian group of firms consisting of E. Phil & Søn, Copenhagen, Denmark; Østlunds Byggnadsaktiebolag, Stockholm, Sweden; and Grävmaskiner, A. B., Stockholm, Sweden, who co-operated under the name of Fosskraft.

The consulting engineers were A. B. Berdal, Oslo, Norway, for the civil-engineering work, and H. Thoresen, mechanical engineer, Oslo, for the turbines, while the electrical equipment was partly controlled by the power company itself and partly by

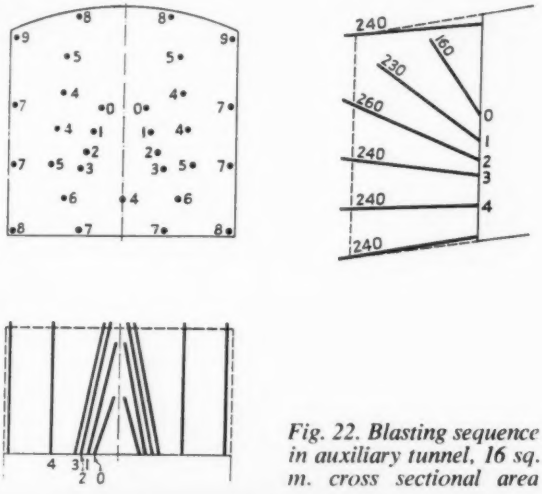
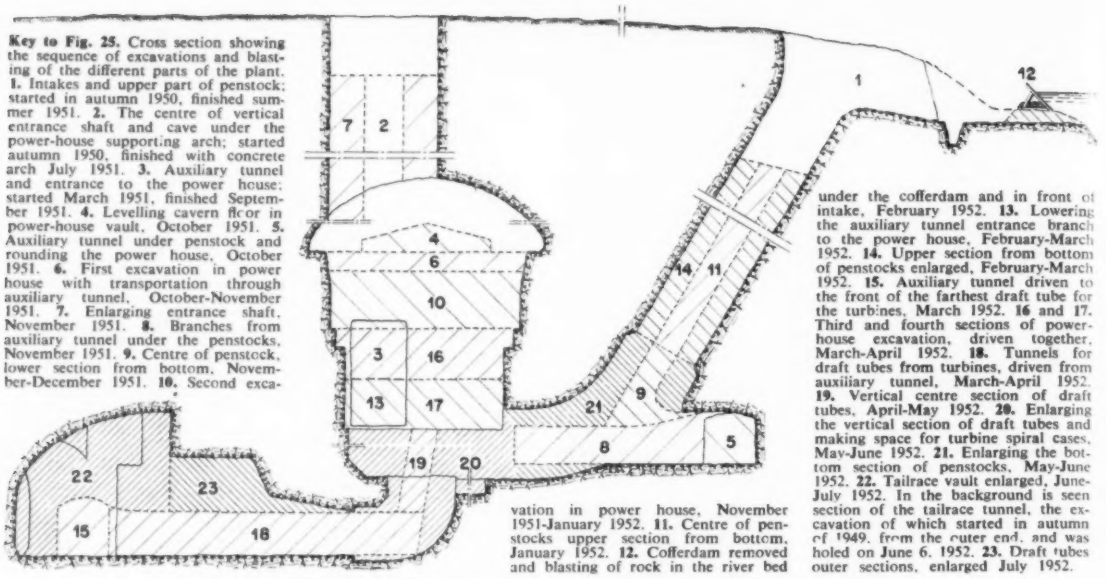


Fig. 22. Blasting sequence in auxiliary tunnel, 16 sq. m. cross sectional area

Fig. 23. Auxiliary tunnel; branch on right is the entrance to power house and that on left goes to tailrace chamber



Key to Fig. 25. Cross section showing the sequence of excavations and blasting of the different parts of the plant. **1.** Intakes and upper part of penstock; started in autumn 1950, finished summer 1951. **2.** The centre of vertical entrance shaft and cave under the power-house supporting arch; started autumn 1950, finished with concrete arch July 1951. **3.** Auxiliary tunnel and entrance to the power house; started March 1951, finished September 1951. **4.** Levelling cavern floor in power-house vault, October 1951. **5.** Auxiliary tunnel under penstock and rounding the power house, October 1951. **6.** First excavation in power house with transportation through auxiliary tunnel, October-November 1951. **7.** Enlarging entrance shaft, November 1951. **8.** Branches from auxiliary tunnel under the penstocks, November 1951. **9.** Centre of penstock, lower section from bottom, November-December 1951. **10.** Second excavation in power house, November 1951-January 1952. **11.** Centre of penstocks upper section from bottom, January 1952. **12.** Cofferdam removed and blasting of rock in the river bed under the cofferdam and in front of intake, February 1952. **13.** Lowering the auxiliary tunnel entrance branch to the power house, February-March 1952. **14.** Upper section from bottom of penstocks enlarged, February-March 1952. **15.** Auxiliary tunnel driven to the front of the farthest draft tube for the turbines, March 1952. **16** and **17.** Third and fourth sections of power-house excavation, driven together, March-April 1952. **18.** Tunnels for draft tubes from turbines, driven from auxiliary tunnel, March-April 1952. **19.** Vertical centre section of draft tubes, April-May 1952. **20.** Enlarging the vertical section of draft tubes and making space for turbine spiral cases, May-June 1952. **21.** Enlarging the bottom section of penstocks, May-June 1952. **22.** Tailrace vault enlarged, June-July 1952. In the background is seen section of the tailrace tunnel, the excavation of which started in autumn of 1949, from the outer end, and was holed on June 6, 1952. **23.** Draft tubes outer sections, enlarged July 1952.

Fig. 24. Cross section showing sequence of operations in excavating pressure shaft, power house, access shaft and tailrace tunnel

Fig. 25. Tailrace tunnel after lining

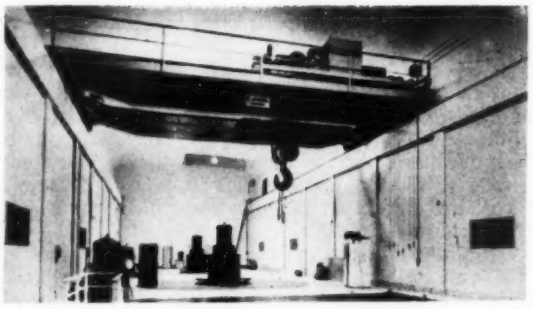


Fig. 26. Machine hall

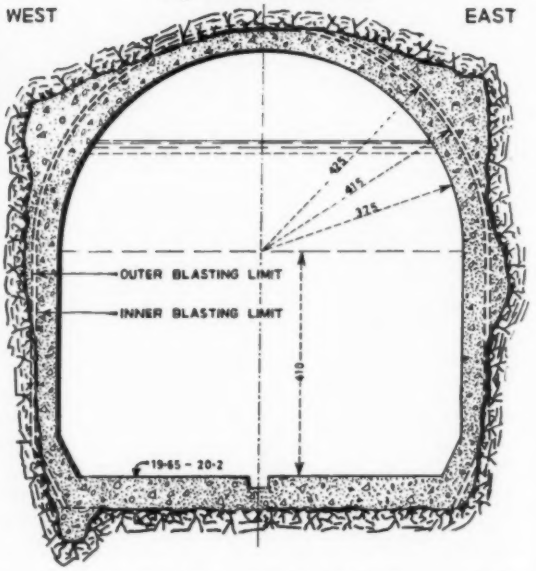


Fig. 27. Section of tailrace tunnel with concrete lining

E. G. Eggertsson of New York and Winnipeg.

Karlstads Mekaniska Werkstad, Sweden, were responsible for the hydraulic turbines, while Westinghouse Electric Int. Co. of New York supplied the generators, transformers and switchgear.

The transformers and switchgear in Reykjavik were manufactured by the General Electric Int. Co., New York, and the steel towers for the transmission line by the U.S.S. Steel Export Corporation, also of New York.

Erection of the machines and the equipment, as well as the building of the transmission line, was undertaken by the power company itself under supervision of the manufacturers. The cost of the power plant was equivalent to £2,860,000, and the cost of the transmission line and main transformer station amounted to £780,000. The work was started in August 1950 and the station was put into operation in October 1953.

Book Reviews

Kempe's Engineer's Year-Book. Published by Morgan Brothers (Publishers) Limited, 28, Essex Street, Strand, London, W.C.2. 1955. Two volumes in case measuring 7¼ in. x 4¾ in. x 4⅛ in. 2,858 pp. Illus. Price 75s. net, postage 2s. 6d.

This useful year-book has now achieved its 60th edition, having been started in 1894. With a prestige that has gathered with the years it is now scarcely possible to conceive an engineer's office without these ubiquitous volumes, for every engineer is in need of basic data on occasions and nothing is more certain than that they will be found in Kempe.

Having regard to the drastic remodelling that the year-book underwent last year it is not surprising that the revision for the current issue should have been confined to matters of detail, new information, for example, having been added to the chapters on electronic engineering, explosives, and flow metering and mechanical testing. Other modifications concern an improvement of the index system, which has been effected by increasing the number of cross-references in the text, thus ensuring a readier access to the information required.

Irrigation and Hydraulic Design. Vol. I. General Principles of Hydraulic Design. By Serge Leliavsky, Ph.D., M.I.C.E., M. Am.Soc.C.E. Published by Chapman & Hall Limited, 37, Essex Street, London, W.C.2. 1955. 492 pp. (including index). 314 ff. 10 in. x 7½ in. x 1½ in. Price 126s. net.

This work has been planned for three volumes and the present book, comprising three sections, is devoted to the more fundamental principles of design with special reference to percolation in granular foundations under hydraulic structures and in earthern embankments, tail erosion in all its aspects, and considers hydraulic flow in canals and rivers, both uniform and non-uniform. As may be gathered from the fact that 480 pages are devoted to these subjects, the treatment is thoroughgoing and exhaustive although the author's style is essentially direct, objective and condensed. All theoretical aspects are fully discussed in the light of leading authorities and the practical examples cited, although chiefly concerned with conditions in Egypt, where the author was formerly Director of the Designing Service, Reservoirs and Nile Barrages Department, offer a range of problems sufficient in variety to be of value to the hydro engineer no matter in which part of the world he is practising.

Each of the three chapters is divided into a varying number of sections, the subjects discussed in Chapter I including the essential points which need to be considered in the design of barrages, regulators and weirs to provide safety against undermining, uplift and bed erosion. Other sections in this chapter deal with the flow of water through a pervious soil, percolation as a factor in estimating the structural safety of an apron, the theory of stream lines, the main principles of the conformal transformation method, Khosla's first problem, Pavlovsky's problem, graphical experimental methods for flow-net diagrams, Khosla's second problem, non-homogeneous fields, Professor Lane's problem and the weighted creep theory, and the underground erosion concept and its effect on foundation design.

In Chapter II, tail erosion is considered under the following sectional headings: solutions derived from experience with existing works, model tests, the standing wave, the erosion of solid work, and erosion experiments with non-aqueous liquids.

Chapter III, which discusses the hydraulics of canals and rivers, is divided into two sections, the first covering uniform flow and the second, non-uniform flow and back-water curve analysis.

An excellent bibliography is incorporated in the text, and the index, which leaves nothing to be desired, is separated into a subject index and a name index, a point of considerable convenience to the reader. Chapman & Hall Limited have made an admirable job of the production of the book, and the paper, type, illustrations and binding are fully in keeping with an important textbook of this kind.

The Friction Coefficient for Circular Pipes at Turbulent Flow. By J. R. Finniecome, M.Eng., M.I.C.E., M.I.Mech.E., F.Inst.F., M.Soc.Ing.C., A.M.I.E.E. Emmott & Co. Ltd., 31, King Street West, Manchester 3. Price 10s. net.

The problem of determining flow in pipes is conditioned, not by any paucity of data but by the difficulty of correlating the wealth of information available. Mr. Finniecome has set out to provide such a correlation, and in so doing he has rendered a valuable service to the designer. He has examined the mass of experimental data and the numerous friction-coefficient formulae both for smooth and for rough pipes and has compared them, the calculated results being tabulated and finally presented graphically. To assist in the correlation, the various formulae are reduced to the well-known form

$$\Delta p = (\lambda/144)\ (w^2/2g)\ (L/D) \times \gamma$$

In examining the data on smooth pipes the author concludes that the Blasius-Nikuradse (1932) graph is most suitable for determining the friction coefficient. With regard to rough pipes he considers Nikuradse's test data and graphs on artificially roughened pipes to be of immense value.

Mr. Finniecome is one of Britain's leading designers of steam turbines, but as his study has been concerned impartially with results obtained with steam and with liquids, his book should be of direct interest to hydraulic engineers.

Rules Governing the Short-Circuit Testing of Air-Break Circuit Breakers for Alternating-Current Systems. Publication No. 16. The Association of Short-Circuit Testing Authorities (Inc.), 36 Kingsway, London, W.C.2. Price 10s. net.

These Rules have been formulated to secure uniformity in the short-circuit testing of air-break circuit breakers pending the completion of clause 40 of B.S. 862-1939 and the publication of a British Standard for air-break circuit breakers for voltages exceeding 660 V. Until such standards have been published the Association will issue certificates of short-circuit rating for circuit breakers passing the prescribed tests. When the British Standard is published it will supersede these Rules. This publication has been formulated not only to secure uniformity of testing, but also to provide all the data necessary, within a single document, to conduct these tests.

Present Trends in the Design of Pressure Tunnels and Shafts

An abstract is given of a paper presented to the Institution of Civil Engineers by Charles Jaeger, Dr ès Sc. Techn., the text having been modified in places in the light of contributions made to the discussion.

PART TWO

IF the rock, before blasting, was in plastic equilibrium and completely constrained, it begins to creep when pressures are released by the blasting. This creep may be slow, but there are indications that very brisk displacement may follow the instantaneous release of pressure.

The next difficulty concerns the measuring technique to be used. This is illustrated in Fig. 7. An extensometer is fixed to the rock surface. The rock is then bored round the extensometer, which remains on the bore core. A borehole diameter of 235 mm. has been used in France.† As the boring progresses, the pressure round the core is relieved and the readings of the extensometer are recorded. Fig. 9 shows how, when the depth of the cylindrical boring increases, the strains recorded by the extensometer increase, the ratio between the principal stresses tending towards a constant value, which, for this particular case, is rather higher than unity. The tests to which Fig. 9 refers were made inside the test tunnel of Montpezat. Although, for these measurements at Montpezat, an alternative method was used the results are similar. A horizontal channel is cut out of the rock and a Freyssinet-jack, as used for prestressing concrete, is inserted into the split and grouted into the rock (Fig. 8). Extensometers are disposed on the rock surface at convenient angles, so that zero readings correspond to the conditions before cutting out the horizontal channel. After excavation, the pressure inside the jack can be read directly when the readings on the extensometers are readjusted to zero. With this method, the pressure is measured directly, thus eliminating a possible error in calculating the modulus of elasticity E.

In a third method, the strain meter is arranged for insertion into a borehole of 56 mm. diameter. A co-axial core drill with a diameter of 250 mm. relieves the stresses in the central core. Readings are taken in three directions in order to ascertain the direction of the principal stresses. This method has been used at Isère-Arc[64] but the results have not yet been published.

Behaviour of the Rock Round a Cylindrical Hole or Gallery

In order to interpret correctly the results of rock measurements and for a better understanding of the modern theory of the stability of tunnels and galleries, some further remarks are essential.

It has already been mentioned that drilling a hole or blasting a tunnel profoundly disturbs the pressure distribution in the rock.

Several authors[25,26,27,28,29,30,43,44,45,46] have analysed the behaviour of the rock round a cylindrical tunnel, while there was no internal pressure ($p=0$) in the tunnel. If the rock pressure p^* produced by the rock's own weight is acting on the circular contour of the tunnel in one direction (vertical) only, the stresses at

† This method was first used in Italy by Oberti at Venina, where an annular channel of 2 to 3 metres diameter and 0·5 metre depth was excavated round the extensometer.[43, 44, 45]

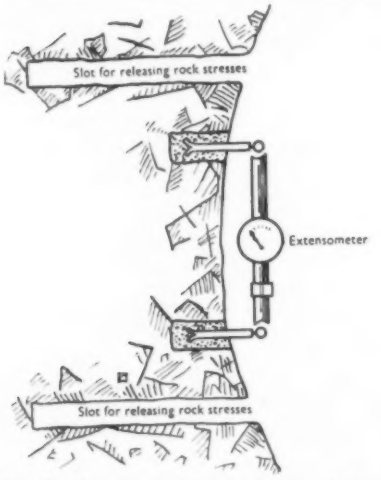


Fig. 7. Measurement of rock strain inside a tunnel (after Oberti and Talobre)

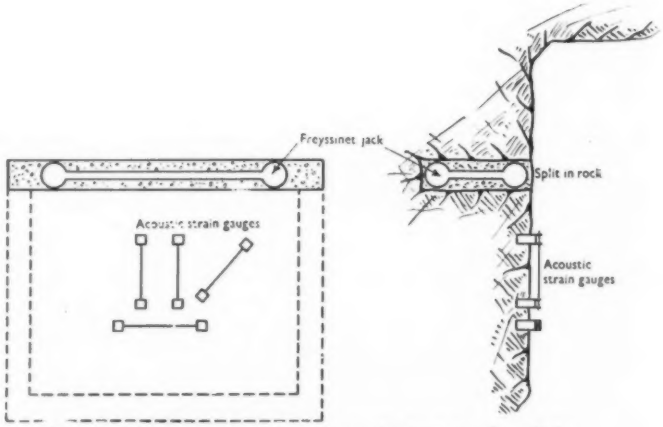


Fig. 8. Measurement of rock strain in tunnel wall by the Freyssinet-jack method

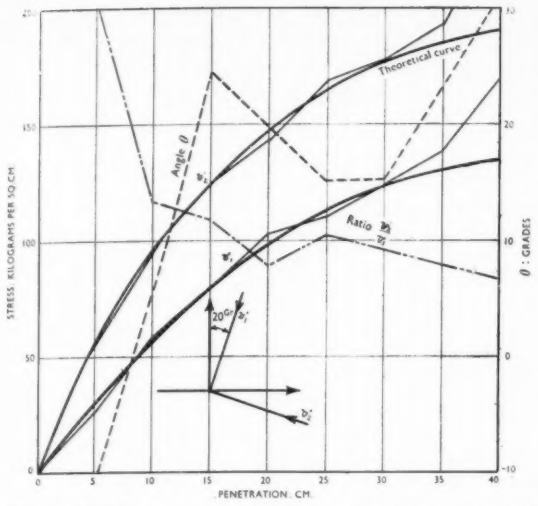


Fig. 9. Natural principal stresses in gneiss measured inside the gallery at Montpezat (after Talobre)

the tunnel wall on the horizontal axis Oy are, according to Timoshenko: $\sigma_r=0$; $\sigma_t=3p^*$ (see Fig. 10(a)).

In addition, the theory shows that on a diameter parallel to the pressure p^* (vertical diameter) the stresses are tensile: $\sigma_t = -p^*$. Strains should be observed at the soffit of tunnels if the picture given by the theory were true, and tunnels filled with water at pressure p, causing an additional circumferential stress $-p$, would leak.

The recent theory of Terzaghi and Richart,[19] introducing a component in a direction normal to p^* (due to Poisson's ratio), shows that the stresses are (Fig. 10(b)):

$\sigma_t < 3p^*$ on a horizontal diameter.

$\sigma_t > -p^*$ on a vertical diameter.

If the pressure p^* has the character of a hydrostatic pressure ($p_x=p_y=p^*$) (Heim) the stresses on the axis Oy are, as shown in Fig. 10(c): $\sigma_r=0$; $\sigma_t=2p^*$ for any diameter.

The following remarks are based on the assumption that the theory of Heim is true and that the initial pressure distribution in the rock is of the so-called hydrostatic type, which causes the pressure at the border of the tunnel to be doubled ($\sigma_t=2p^*$) after excavation of the tunnel. Denoting the limit of elasticity of the rock by σ_{el} and its crushing strength by σ_{cr}, then, if $\sigma_{el}>\sigma_t=2p^*$, the tunnel is stable. If the local pressure σ_t is greater than the limit of elasticity, plastic deformation of the rock will occur. Experience shows that, although the plastic deformation of the rock is very slow, when once begun it is difficult to stop; usually it continues until either the plastic deformation has evened out the stress distribution or the rock is completely crushed and the gallery collapses.

Crushing of the rock will certainly occur if $\sigma_{max}-\sigma_{min}>\sigma_{cr}$. Figs. 13(a), (b) and (c) represent, according to Talobre, the probable distribution of pressure for:

$$\sigma_t=2p^*<\sigma_{el}\ ;\ \sigma_t>\sigma_{el}\ ;\ \sigma_{max}-\sigma_{min}>\sigma_{cr}$$

respectively. It should be clearly understood that these three sketches give only qualitative information, for they cannot take into account the lack of homogeneity of natural rock.

In the case where the distribution of pressure is determined by the gravitational field alone (Fig. 10(a)), the stress distribution can be ascertained by model experiments. Tests made for the Krångede tailrace tunnel[57, 58] (Sweden) showed an ogive cross-section to be more favourable than a circular one (Figs. 12).

Rock Stability and Lined Tunnels

The hydrostatic pressure inside a conduit, gallery, or tunnel filled with water is $p=wH$ (where H denotes head, w the specific gravity of the water). If $p=p^*$ the conditions round the perimeter of the gallery would be identical to those prevailing before the construction of the tunnel and the rock would revert to the original state of uniform stress distribution $p^*=$ a constant (if the rock is assumed to be homogeneous and the overburden deep). It is easy to check that the stress conditions along the perimeter of the gallery then give $p=\sigma_r=-\sigma_t=p^*$, which, added to the stresses shown in Fig. 10(b) ($\sigma_r=0$ and $\sigma_t=2p^*$), finally yield $\sigma_r=\sigma_t=p^*$ everywhere.

A deep tunnel in sound homogeneous rock with internal water pressure $p\leqslant p^*$ would be perfectly safe without any lining, whatever the value of p^*. But rock is rarely sound and homogeneous, and hydro-electric power tunnels and shafts are rarely deep. For these and other reasons the water pressure p should be less than p^* and it is convenient to write $p=p^*/n$, where n has the significance of a safety factor. When using the rule of thumb that the water pressure p inside the tunnel should not be more than half the depth of the overburden ($p=\frac{1}{2}H$), the safety factor n is equal to twice the specific density of the rock, $w=2{\cdot}5$. This gives $n=5$, which seems to be a reasonable safety margin to adopt when one considers the safety factors usually applied to steel and concrete. An approximate estimate of the redistribution of the stresses in the rock after introduction of the water pressure p in the gallery will be obtained by superposing the stress distribution as shown in Figs. 1 on that represented in Figs. 11. These comments summarise the modern views on pressure shaft theory.

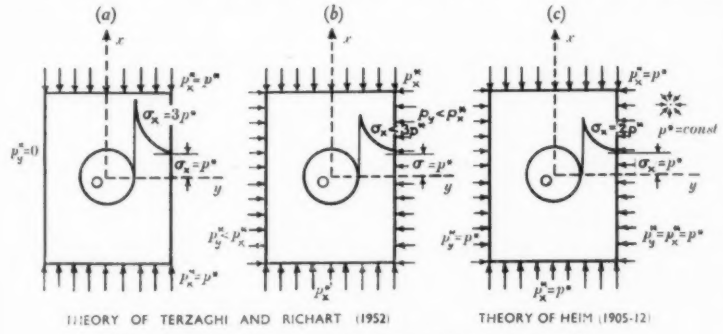


Fig. 10. Stresses in rock around an empty gallery

(*a*) The rock pressure p^* is parallel to direction Ox
(*b*) " " " $p_y<p^*_x$
(*c*) " " " $p^*=p^*_x=p^*_y$ is "hydrostatic"

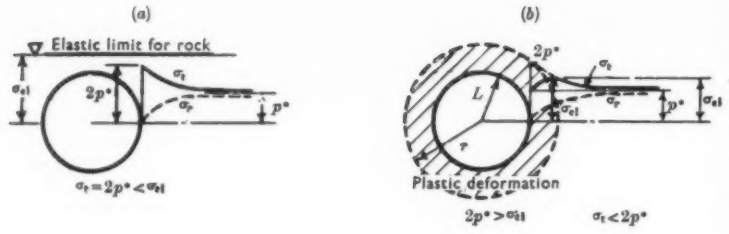
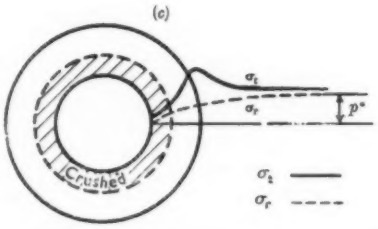


Fig. 11. Stresses in rock around an empty tunnel (after Talobre and others)



If the prestressing in the rock round a deep gallery is of the "hydrostatic" type, then the pressure σ_t round the gallery perimeter is $\sigma_t = +2p^*$ all round and the tangential stresses produced by the water pressure p will easily be absorbed by the prestressed rock without any resulting tensile stresses being produced. The hydrostatic pressure releases the rock stresses around the tunnel bore.

Conditions are quite different when the water pressure p is greater than the prestressing p^* or when, owing to insufficient overburden, the pressure p^* is not of the "hydrostatic" type (that is to say, when there is insufficient horizontal pressure component).

Stress and strain measurements inside tunnels have to be considered as dealing with three-dimensional systems. In several cases, it was thought that model tests were desirable to help interpret the results.

In recent years such basic ideas have led to many new designs, most of them taking advantage of the ability of the rock to absorb pressures. The technique of grouting is of primary importance in the transmission of pressures from the lining to the rock, and is considered in more detail later in the paper. Other methods can be considered, in which prestressing may be used instead of or in conjunction with grouting.

One of the very first attempts to introduce a radial compression stress σ_c in the concrete lining of a pressure tunnel was made at Marèges (Figs. 13). There, Mary[83] incorporated circular cables running outside the concrete lining; these cables were stressed by hydraulic jacks, the stresses in the cables being calculated so that the final resulting circumferential stress σ_c in the lining remained always a compression stress, even when the gallery was filled with water under full pressure.

This is a typical prestressed structure which was devised at a time when the modern methods for pre-

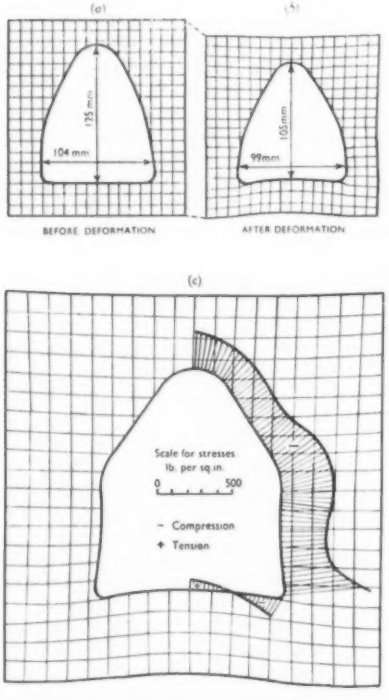


Fig. 12. Model tests on Krångede tail-race tunnel

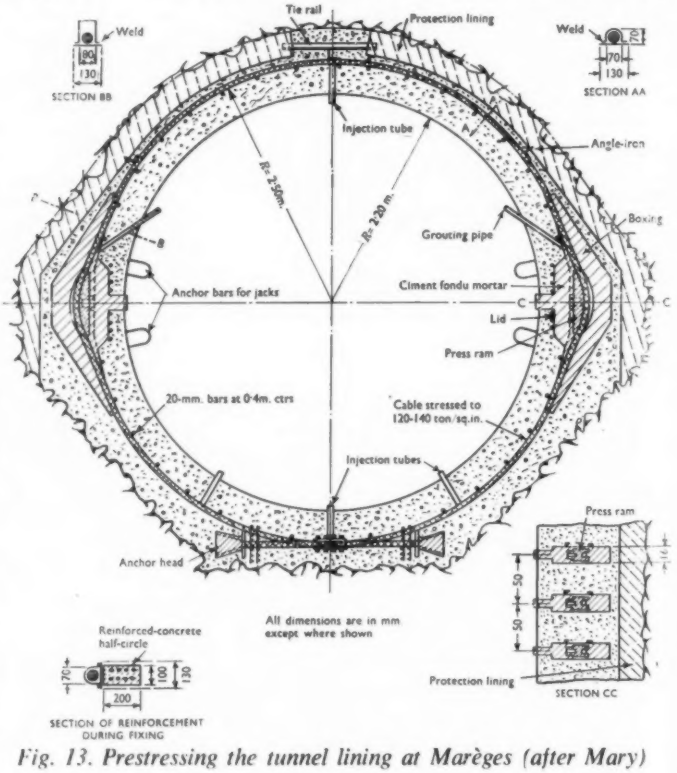


Fig. 13. Prestressing the tunnel lining at Marèges (after Mary)

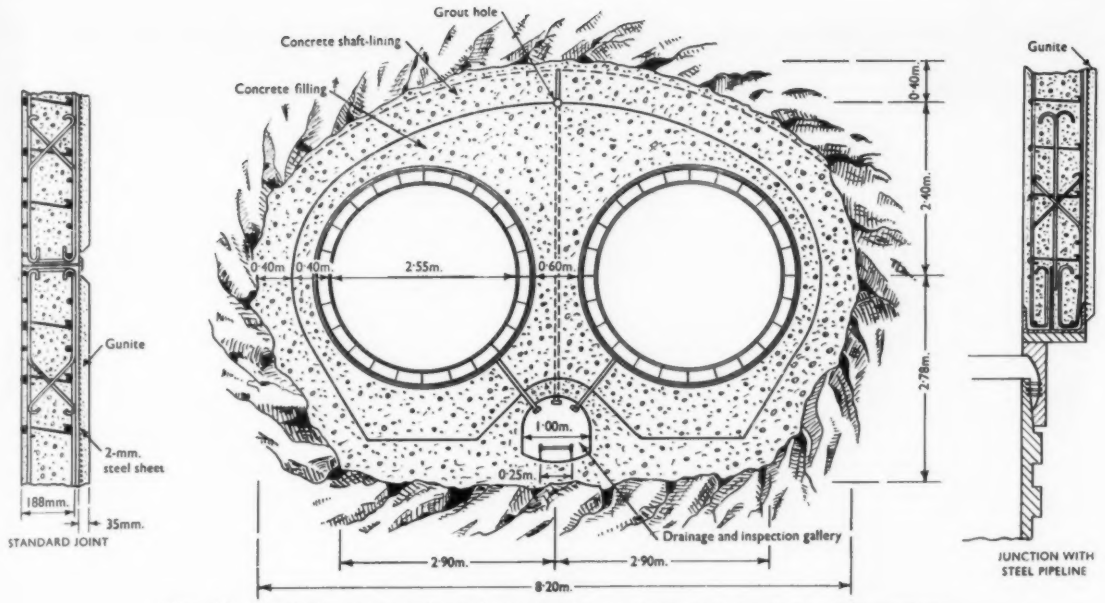


Fig. 14. Typical cross-section through precast concrete penstock at Soverzene

stressing were still in their infancy. With the pressure pipe invented for Marèges, the prestressing method puts all the load on the cables and no advantage is taken of the bulk resistance of the rock. There are other examples of similar constructions.

Kieser has patented a method (to be described later) of forcing grout behind annular rings of precast concrete. An alternative method is to use Freyssinet-type flat jacks placed in the concrete in the direction of generators of the cylindrical tunnel lining. These jacks would produce the circumferential pressure necessary for prestressing the concrete lining.

The four prestressed concrete pipelines of Soverzene[45, 73] are placed in pairs in two inclined shafts of elliptical cross-section. Each section of pipe is 4·5 metres (14 ft. 9 in.) long, 2·55 metres (8 ft. 4½ in.) internal diameter, and 0·19 metre (7½ in.) thick. The sections were precast off the job in a vertical position. High-frequency vibration was used to consolidate the concrete which was poured into the annulus formed between two cylinders of steel plate, the inner of which was collapsible, whilst the outer one, which was 2 mm. thick, remained attached to the concrete and became a permanent watertight lining. After 24 days' seasoning the pipes were armoured around the 2 mm. plate and prestressed with a 5 mm. diameter high-tensile-steel wire; this was done in a machine designed for the purpose. After completion of the armouring, an outer layer of gunite was applied (Figs. 14). The pipes were then placed in the inclined shaft and fitted together by butt-welded joints on the ends of the steel liners. Finally, the space between the pipes and the rock wall was filled in with vibrated concrete.

The 270 mm. diameter pressure conduit at Muccone operates under 120 metres head. The pipe is in concrete, precast in vacuum, reinforced and prestressed with high-tensile-steel wires. A space of 50 mm. was left round the prestressed pipe for grouting with pressure grout.

Adjustable Axial Fan

Quick adjustment to meet varying requirements without upsetting the installation is claimed by Keith Blackman Limited, Mill Mead Road, Tottenham, London, N.17 for their Tornado high efficiency axial fan impeller. It has been designed to permit variation to the geometric pitch of the fan wheel as a whole, by adjusting the angle of attack of the individual blades; alteration of the volume/pressure output can thus be obtained at constant speed without changing the complete impeller or even removing it from its spindle.

Blades of cast aluminium-silicon alloy are mounted by means of high-tensile steel studs on to a one-piece hub cast in the same material. Adjustment is made by removing the front hub cover plate of the fan wheel and slackening each of the blade-securing nuts and locking screws. Each blade may then be twisted by hand as desired and it is claimed that variations as small as one degree can be obtained. Accuracy of setting is ensured by calibrated protractor plates.

Southern Rhodesia Geology. Bulletin No. 41 published by the Geological Survey Office, Salisbury, describes the geology of the country between Concession and Msonneddi (Mazoe District). The author is J. G. Stagman, M.Sc.

Steel Castings. The North British Steel Founders Limited have issued an illustrated booklet under this title, designed to provide a source of reference for the purchaser of castings, as well as listing this firm's products. Sections are devoted to each department of the steel foundry.

Diesel Engines in Hydro-Electric Schemes. In a recent issue of The Technical Journal of The Brush Group there is an interesting reference to diesel-engined generator sets which have been supplied to the North of Scotland Hydro-Electric Board. In all over 12,000 kW of capacity have been installed.

Fig. 1. General view of the Volta river model

Volta River Model

FURTHER to the brief note we published in our December 1954 issue, page 447, about the model of the Volta River constructed by George Wimpey & Co. Ltd. for Sir William Halcrow & Partners, we have now been privileged to inspect the model in operation and to obtain further details.

A résumé of H.M. Government's White Paper on the Volta River Aluminium Scheme was published in our January 1953 issue, page 26, and in Fig. 1 we reproduce a sketch map of the area involved. The objective is to exploit extensive deposits of bauxite that have been proved in the Gold Coast, and to derive the necessary power for an aluminium smelter from the waters of the Volta. The decision whether to imple-

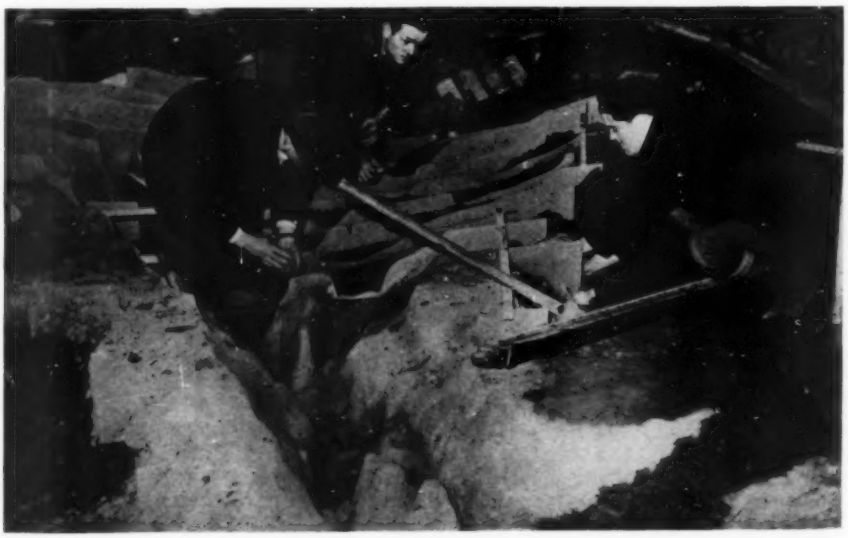


Fig. 2. Filling in the spaces between the contoured sheets

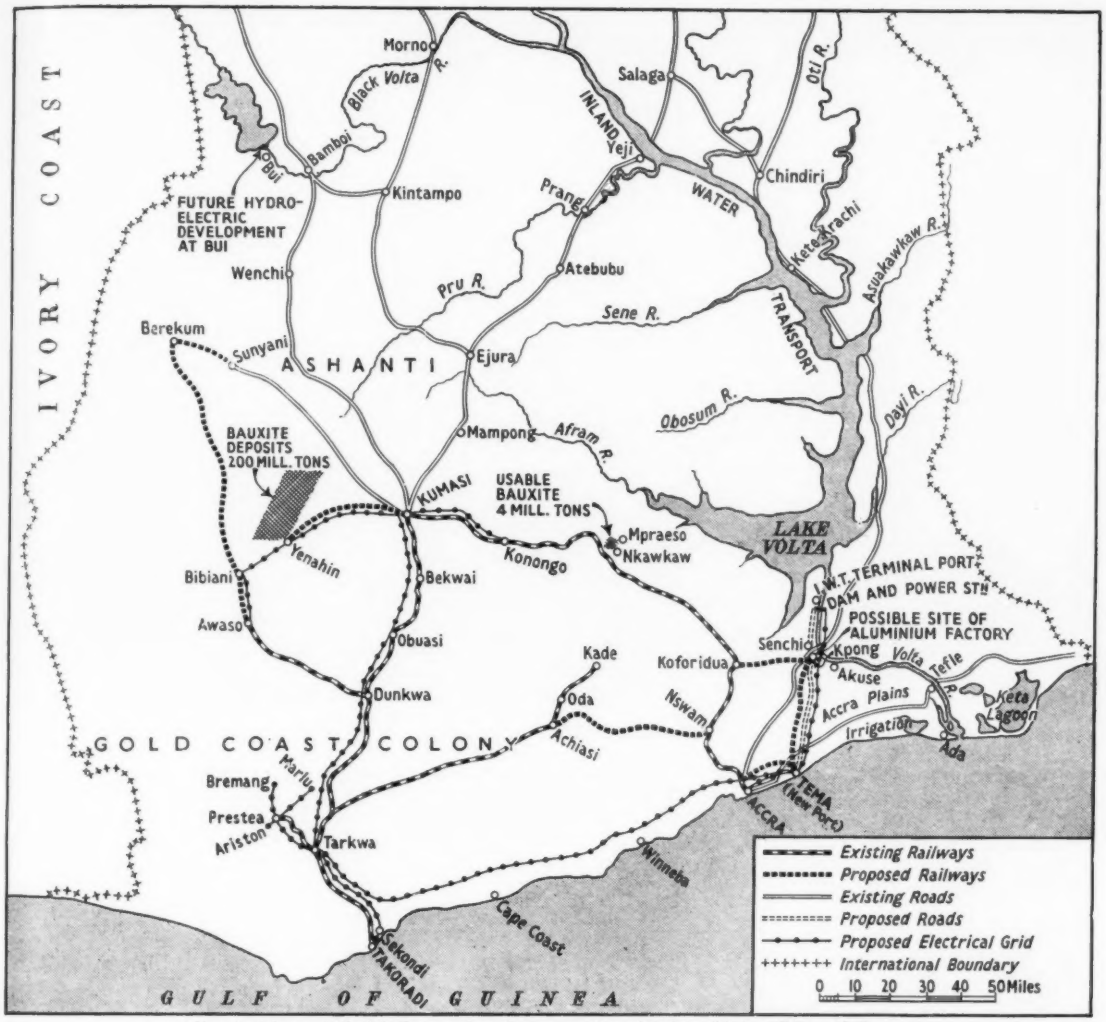


Fig. 3. Map of Gold Coast showing area involved in Volta River Scheme

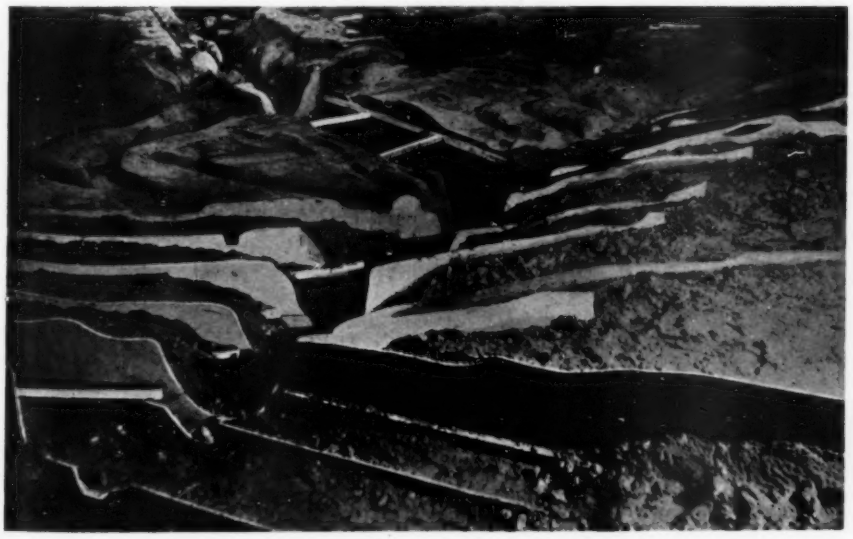


Fig. 4. View of model during constructional stage to show method of obtaining accurately contoured surfaces

Fig. 5. Dam and spillway site, looking downstream from Ajena, being inspected by Gold Coast Commissioner

Fig. 6. First flow test of smooth model, Ajena to Kpong section

Fig. 7. Gold Coast Commissioner watching Volta Bridge site under simulated catastrophic flood conditions

ment the scheme will not be taken by the Gold Coast Government until they have studied the report which will be submitted in due course, but work has already been started by the Parkinson-Howard group of contractors on the new port of Tema, as this is considered essential to the country's economy irrespective of the aluminium scheme, and a contract has been let to Dorman Long & Co. Ltd. for the construction of a road bridge across the river above Senchi.

The Volta River is about 1,000 miles long and has a catchment area of 150,000 sq. miles. Its long-term average flow is 40,000 cusecs, normal dry-weather flow 2,000 to 5,000 cusecs, normal annual flood flow 150,000 to 300,000 cusecs, and theoretical maximum flood 1,200,000 cusecs unregulated and 900,000 cusecs regulated. Such a flood as that just mentioned has never been known to occur, but it represents the calculated maximum and has been taken into account in determining the dimensions of the spillway and other civil-engineering works.

It is proposed to build a rockfill dam at Ajena in the gorge through the Akwapin Hills, a power station adjacent to the dam on the left bank, and a spillway behind the power station discharging to a channel which rejoins the river farther downstream. The dam will be of the rockfill type, somewhat similar in design to the Kenney dam, and will be 310 ft. high by 4,100 ft. long at the crest. It will impound a lake nearly 200 miles long and 3,000 sq. miles in area, believed to be the largest artificial lake in the world. The station may eventually house ten 85 MW sets giving an average output of 579 MW. The spillway will be 880 ft long and will have 13 gate openings each 50 ft. wide by 45 ft. high.

The model was built to study the behaviour of the river downstream of the dam at all flows up to the maximum theoretical flood and to devise any necessary works to keep the station tailwater level at an acceptable value during even the worst floods. It covers an L-shaped stretch of the river from a point a little way above the dam site to one about 30 miles downstream where the river emerges into the Accra plains, and includes the Senchi and the Kpong rapids, which were known two exert a limiting influence on the flow. It is about 150 ft. long by 30 ft. wide and is built to a horizontal scale of 1 : 1000 and a vertical scale of 1:125.

A noteworthy feature was the speed with which the model was built; it was constructed in three months, the moulding of the river bed taking only six weeks. This close schedule was desired by the consulting engineers because the experimental results sought were required urgently, and the happy outcome was due to the collaboration afforded by the contractors and to the methods of construction adopted. The river bed was built by the use of over 700 profiles, which were cut out in thin millboard and set on planed timber rails set accurately to level inside the brick retaining walls. The spaces between the profiles were then filled with lean-mix concrete followed by a final moulding in a lean sand-cement mortar.

Nineteen manometer points have been placed in positions corresponding to gauging stations set up on the actual river, and are connected to a central manometer board surmounted by a map relating each manometer to the point on the river to which it refers. Alternative methods of measurement for checking purposes are provided by a series of stilling wells and by a travelling bridge running on rails and carrying pointer gauges.

Water is derived from a 4,500 gallon reservoir under the downstream end of the model, and is

pumped by a 600 g.p.m. pump to an 800 gallon overhead storage tank. Flow from this tank is measured by a vee notch discharging into a stilling basin at the head of the model. At the discharge end the water level can be precisely regulated by a flap weir and the flow is checked by a second vee notch.

One of the most exacting tasks was the calibration of the model—a process that occupied six months. For this purpose readings were taken at a number of specified flows and compared with the gauging-station readings at these flows on the actual river. The bed of the model was then progressively roughened until the readings corresponded at all flows up to 300,000 cusecs. This involved detailed investigation of every part of the river, and the best method of treatment had to be found by experiment. For instance, although the larger boulders were reproduced this procedure was found insufficient and had to be supplemented by conventional roughening such as the insertion of stones in a definite pattern.

A particularly interesting aspect of the calibration process was the problem of reproducing the hydraulic effect of the African bush. The solution was found in the use of wood wool stuck on to the model with paint, teased to an appropriate consistency, and trimmed on the flat areas to correspond to the average height of the actual bush. Detailed maps, photographs and stereoscopic photographs were obtained to determine the type of bush in each region and the roughening adjusted accordingly. These photographs and data enabled the treatment to be extended to those portions of the valley that had never been flooded within living memory but would be involved in the theoretical maximum flood. Thus it has been possible to extrapolate the behaviour of the river under this theoretical flood with some degree of assurance. Incidentally, a model of the new bridge was placed in its appropriate position and the clearance at maximum theoretical flood was checked.

After calibration had been completed the essential work of determining the behaviour of the station tailwater level at all possible flows was undertaken. In addition it was known that the rapids at Senchi and Kpong imposed a barrier to the easy evacuation of normal average flows and one of the purposes of the investigation was to determine what works would be required at these rapids to reduce the normal tailwater level at the station. Ultimately it was decided to cut a single channel through the Senchi rapids and two lesser channels through the Kpong rapids. It was not until a number of alternatives had been tried out that the most favourable dimensions for these channels could be determined.

At the time of writing, the investigation has just been completed, and the results will be embodied in the report which Sir William Halcrow & Partners will present in due course to the Volta River Project Preparatory Commission of the Gold Coast.

Correspondence

High-Head Penstocks in the Rockies

To the Editor of WATER POWER

In the October 1954 issue you published a most interesting article about the design and construction features of the penstocks for the Pole Hill and Flatiron power plants in Colorado, by Mr. Peter J. Bier. It is stated that three types of joints are used: welded, riveted, and Dresser-coupled. It would be most interesting if Mr. Bier would explain in some detail why the three types were used and the reasons for the selection of each. It is interesting to note that the design adopted for these penstocks is rather unique for the Bureau of Reclamation, considering that all recent Bureau penstock designs have welded joints.

C. S. OSPINA

Olarte, Ospina, Arias & Paytan Ltda.,
Bogota, Colombia.

Dear Mr. Ospina,

The Editor of WATER POWER, London, has sent me a copy of your letter of December 3, 1954, which you directed to him in reference to my article on the Pole Hill and Flatiron penstocks in Colorado. In the following I will give you the basic reasons for permitting the use of alternate welded, riveted and Dresser-coupled joints for the field seams of pipe sections made from heavy plates.

The penstocks were designed in accordance with the API-ASME code for unfired pressure vessels, 1943 edition. According to this code, pipe sections fabricated from carbon steel as A285 are required to be stress-relieved, if welded, when the nominal thickness of the plate at any welded joint exceeds 1¼ in. or D1 plus 50/120, (where D1 is the inside diameter of the pipe). Pipe sections made from carbon-silicon steel as A212 are to be stress-relieved when the thickness of the plate at any welded joint exceeds 1 in. or D1 plus 50/120. In conformance with this rule it would be mandatory to apply local stress relieving to the girth joints welded in the field. As such localised stress-relieving has so far proved to be a failure it was ruled out, which led to the reluctant use of riveted field joints. As Dresser couplings had in recent years proved their value as field girth joints they were specified as alternates to the riveted joints in the hope that they will be used in the low bid. Although one of the two bidders based his quotation on the use of Dresser couplings, the low bidder quoted a higher price for Dresser-coupled penstocks than for the riveted construction. Consequently the award of the contract had to be made on the use of riveted field joints for the heavy sections requiring local stress-relieving if welded.

After the award of the contract to the Southwest Welding & Mfg. Co. of Alhambra, Calif., the contractor, realising the various advantages of the Dresser couplings—such as ease of installation, flexibility, elimination of expansion joints, etc.—replaced a number of the riveted joints with Dresser couplings.

I have retired recently from the Bureau of Reclamation and am now doing consulting work on penstocks and steel pipe lines. If I can be of any service to you in this field please advise.

P. J. BIER
Consulting Engineer

680 South Gaylord Street,
Denver 9, Colorado, U.S.A.

Canadian Power Outlook

A prediction is made that Canada will soon be the highest per capita user of power in the world.

By H. G. COCHRANE

LEADERS in Canada's power industry often proudly refer in after-dinner speeches to the rapid growth in the utilisation of the nation's vast power resources. Norway, with 1·3 h.p. installed per capita, still holds first place. Canada as a whole, with just under 1·2 h.p. per capita, is rapidly catching up. Switzerland, currently in third place, claims 0·9 h.p. per capita. The Province of Quebec, if considered alone, tops all areas with 1·8 h.p. per capita.

Canada today is the fastest growing nation of the world. Economists, industrial leaders and demographers, gathered at Quebec City a year ago to discuss "Canada's Tomorrow," confidently predicted that her population will grow to 20 million people by 1970. The country's 65½ million horsepower of commercial hydro potential represents an inexhaustible asset of great value. Many power sites, strategically located in relation to large industrial centres, and assured of well regulated flows, are already furnishing the cheapest power in the world. Even if the present rate of utilisation is merely maintained over another fifteen years, a further six million horsepower would be needed to keep pace with this predicted population growth.

But there are strong indications that such an estimate will be greatly exceeded. There is also a steady growth both in the load factor and in the use of electrical energy in relation to the labour force employed, as well as in the annual bills to residential customers and the number of new dwellings being built.

Fourfold Increase in Next 20 Years

Addressing the Montreal Branch of the Engineering Institute of Canada in June 1953, A. G. Christie, Research Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, spotlighted the ever-increasing utilisation of electrical energy. Pointing out that studies of the growth of power systems indicated that peak loads have increased, over long periods, at an average cumulative rate of 6 to 7 per cent. per annum, doubling in about 11 years, he predicted that by 1975 peak loads would be increased fourfold over the demand in 1953. With water power installations then standing at some 13 million horsepower in 1952, he forecast total installation in 1975 to be some 53 million horsepower, which, if our population has then reached 22½ millions, would represent a per capita use of 2·3 h.p. per capita. Today, some 2 years later, installed power, both hydro and thermal, is close to 18½ million horsepower.

Continuing, the speaker quoted Federal Department of Resources and Development estimates to show that at ordinary six-month flow, Canada's potential hydro capacity amounted to 66 million horsepower; but, for various reasons, possible economic hydro sites might by 1975 provide a capacity at ordinary minimum flow of only some 21 million horsepower. Of the difference between these figures, 26 million horsepower is represented by capacity available for 6 months only.

The difference between estimated demand in 1975 of some 50 million horsepower and the capacity available at ordinary six-month flow of 47.5 million would therefore be close to 2·5 million horsepower. This, he said, would have to be supplied from other sources He concluded that the 26 million horsepower available for 6 months only would require to be supplemented by other types of power plant. If one-third of this capacity were assumed as standby plant, an additional capacity of some 8¾ million horsepower must be provided by installations other than hydro. Thus over 11 million horsepower altogether must be provided by thermal or thermo nucleur plants.

CEA Symposium on Demand

Last summer's annual convention of the Canadian Electrical Association brought partial confirmation of Dr. Christie's predictions. During a symposium on the subject of "The Demand For Power," leading engineers and executives in the utility field outlined the potential power resources in each of the five regions of Canada; Pacific, Prairie, Ontario, Quebec and Maritimes, with forecasts of future demand for various periods of time.

Western Regions. British Columbia's installed capacity at mid-1954, according to T. Ingledow, Vice-President of B.C. Electric, totalled to approximately 1,900,000 h.p., 605,000 of which represented British Columbia Electric installations in the thickly populated lower mainland, where installed power had grown from 249,000 h.p. in 1946 and will increase to 925,000 h.p. by the end of 1957 due to completion of plants now under construction. Though no annual

Fig. 1. Sketch map showing Hamilton River and Grand Falls in relation to iron ore deposits

rate of growth for the province as a whole was predictable, it would appear that installed power doubles in about an 11 year period, and could thus reach some 4·2 millions in 10 years and between 7 and 8 million in 20 years. Available hydro resources on the Fraser and Cheakamus within transmission distance from Vancouver total to some 3.2 million horsepower, while total potential for the whole province was estimated at 11 million horsepower.

Central Provinces. Present installations in the three prairie provinces were reported by W. D. Fallis, General Manager, Manitoba Power Commission, at 453,000, 196,000, and 545,000 horsepower for Alberta, Saskatchewan and Manitoba respectively, a total of 1,194,000 h.p. The rates of increase forecast for the next decade were 11 per cent. yearly for Alberta, a growth to 2·8 times present capacity in 10 years for Sasketchewan and a growth of 109 per cent. in 10 years for Manitoba. This represents an increase in capacity amounting to 1,606,000 h.p. in the next decade, a total of 2·8 millions by 1964 and perhaps 4 millions by 1974.

Ontario, with some 4,500,000 h.p. installed at the end of 1953, will double its capacity in about ten years or at the long term rate of 6·7 per cent. per year, stated Dr. R. L. Hearn of the Ontario Hydro-Electric Power Commission. At such a rate the peak load might increase to around 9 million horsepower by 1965 and might reach 18 million by 1974. Ontario, however, has limited hydro resources, and would have either to import from Quebec or rely on thermal or thermo-nucleur power for most of its future needs after Seaway Power is absorbed in the early 'sixties.

Quebec installations have in the past been doubling every 7 years, reported Dr. Huet Massue of Shawinigan Power. Present total installations at 7,720,000 horsepower will be increased by developments at present under construction to around 9·3 million by 1956; while if the same growth is continued the peak should reach to around 22 million in 1976. Quebec is well off for undeveloped power resources, with some 18 million horsepower still undeveloped.

Maritimes. That the future of the Maritime Provinces, with slightly over 1 million horsepower developed to date between them, is more difficult to assess, was very evident. Nova Scotia has very limited further hydro resources, and will need perhaps 160,000 additional horsepower over the next decade. New Brunswick, with 229,000 h.p. installed, has ample further hydro power available in the St. John river basin and load has been doubling every seven years. Newfoundland, with 292,000 h.p. installed, can count on an additional half-million horsepower, not including the Hamilton River. The Maritimes between them might thus require some 1·8 million horsepower over a decade and a further 3 million over the next 20 years.

While growth of population in industrialised areas can be predicted, these yardsticks cannot be applied to the areas adjacent to the more remote projects on the Northern rivers. Growth here is based on vision and enterprise. In some instances these powers will be transmitted at high voltage to more settled areas.

New Percapita Records

Summarising the above forecasts thus indicates a possible total demand for all Canada of some 28 million horsepower by 1964 and at the same geometric rate of growth, to some 50-60 millions by 1974. It will be noted that these figures exceed even Dr. Christie's forecast. If Canada's population, presently approaching 16 millions, grows to the predicted 20 millions over the next fifteen years, the per capita installation of power for Canada as a whole would thus increase to about 1·5 h.p. per person by 1964 and to somewhere beween 2¼ and 2¾ h.p. per capita by 1975. Some optimists are visualising 30 million people in Canada within 20 years, and this population, if realised, would mean an increase of the per capita installation of between 1¾ and 2 h.p. only; but even this figure would top all previous records, except possibly those for Quebec.

Where will all this power come from? Some of the regions, notably Saskatchewan, Ontario and Nova Scotia, have very limited hydro power resources yet to develop. Other provinces, such as British Columbia, Quebec and Newfoundland, have probably more than they will need for many years to come.

Several of the larger potential sources not mentioned for example those on the Yukon, Columbia, Peace, Churchill, Hamilton, and rivers running into James and Hudson Bays, are too far from present centres of population, and development must await the financing of large metallurgical projects close to the sites. On the other hand, regions deficient in hydro resources must rely on thermal or thermal-nuclear power, or from gas turbines fuelled by Western Canada's vast supplies of natural gas.

Broadly speaking, however, the potential hydro resources mentioned by the various speakers at the CEA symposium as being within available transmission distance of the present centres of Canadian population and industry, add up to some 16 million horsepower. Added to the total of all power presently installed of around 18¼ million, this shows a total of close to 35 million horsepower. Adding to this the several large but more distant resources presently under study, such as the reported 5 million on the Yukon, 7 million on the Hamilton River, 2 million on the Nelson and another 3 million on the Columbia, it is not difficult to foresee a possible 50 million horsepower under development within 20 to 25 years.

The Yukon Project

A power and ore-smelting and refining project of startling proportions is planned to utilise the waters of the Yukon River as a source of cheap power. Conceived by Thayer Lindsley, president of Frobisher Ltd., and Ventures Ltd., the project would require seven years or more to complete. $270 millions would finance the first stage for the development of 880,000 h.p., as well as the incidental smelters and refineries. Ultimately the project would utilise between 4 and 5 million horsepower.

In brief outline, a dam on the north-flowing Yukon River, some 800 miles north of Vancouver, would divert part of its flow southward into an extensive lake-studded watershed, east of the coastal range, extending south-eastward more than 200 miles to a point some 80 miles south of the Yukon Territory—British Columbia boundary. The water, stored at an elevation of 2,200 ft. above sea level, would be dropped through tunnels south of Atlin Lake to the generating plant. From here the power would be transmitted 45 miles to Taku, where smelters and refineries would be built at tidewater on an inlet a few miles east of the Alaska Panhandle border.

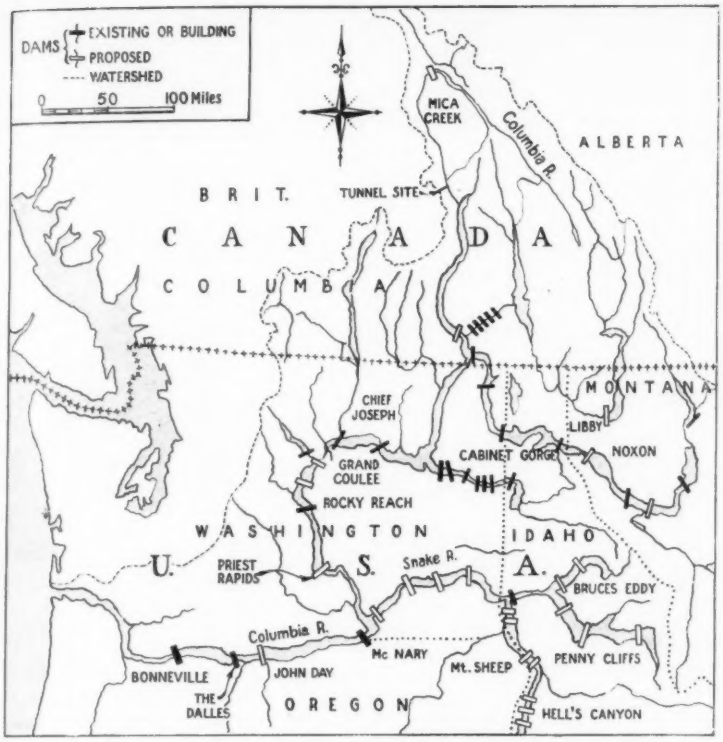


Fig. 2. Map showing southern part of British Columbia, in relation to Washington, Idaho, Montana and Oregon, indicating location of existing and proposed hydro-electric schemes

Power, not Coal, the Magnet

Following the example set by the Aluminium Company of Canada, at Kitimat, of bringing the ores by ship to the site of the cheap electric power, Lindsley plans metallurgical and chemical industries on a scale never before seen. Nickel and cobalt concentrates will come from the Netherland East Indies and New Caledonia. Iron ore will come from British Columbia and Alaska, other ores from South America, West Africa and Uganda. He sees Taku as another Swansea, Wales, where Welsh coal has been the magnet for drawing world-wide ores to coal-fired smelters there for a century or more.

The first step would be to build a new test concentrator near Vancouver of 100 tons per day capacity, with electric furnaces. The concentrates would then go to Cobalt, Ontario, for final refining and thence to the ultimate users. An electrical steel mill would also be built nearby to smelt 100 to 150 tons of iron ore daily from Vancouver Island.

One problem not yet fully solved is to find access to deep water on Canadian territory. At the end of Taku inlet, salt water penetrates the Alaska Panhandle to within 10 miles of the Canadian border. On Canadian soil is a promising industrial site at Tulsequah, B.C. But engineers for American metal interests allied with the project, are studying alternative sites down the inlet on Alaska territory.

Hamilton River, Labrador

The greatest single source of undeveloped hydro power remaining in Canada today is the Hamilton River in Labrador. Grand Falls itself has a potential of some 3 million horsepower, while the rapids below it, together with a further site 200 miles downstream at Muskrat Falls, are said to have a further potential of 4 million horsepower, making a total of 7 millions.

This project has been surveyed and studied jointly by Shawinigan Engineering Co. and Montreal Engineering Company, on behalf of the British Newfoundland Corporation, a Crown company, formed early in 1953 to explore and where justified, to develop power and timber resources on concessions granted by the province.

Grand Falls is roughly at the eastern apex of a triangle whose western side, 100 to 150 miles away, runs through both ore bodies of the rich iron deposits now being worked. The Hamilton River Basin drains into the Atlantic rather than southward into the Gulf of St. Lawrence. The Corporation has a concession for the power development at Grand Falls and holds mineral and timber rights in Labrador.

The Falls are located in an isolated region 550 miles north-east of Quebec City. The drop is 250 feet. According to General A. G. L. MacNaughton, Canadian Chairman of the International joint commission, the project would produce the cheapest power in Canada, and possibly the cheapest in the world. Its importance is emphasised by the fact that Ontario has now developed all its major water-power sites and will soon have to build thermal plants to supplement hydro supplies.

Improvement in transmission techniques, including the use of much higher voltages, will make it economically feasible to transmit much of the output of this scheme to tie in with power networks in the highly industrialised central provinces. By using the Thury system of transmission it is believed that it will be practicable to transmit blocks of power 750 miles distant to Ottawa, to tie in with Ontario's hydro network, Quebec province being well supplied with undeveloped hydro resources of its own.

Principal backers include N. M. Rothschild and Sons; Bowater Paper Corp. Ltd., Anglo-Newfoundlond Development Company Ltd., Frobisher and a number of others. Recently Premier Smallwood of Newfoundland announced that the Company had already spent a million dollars and were examining the potenial market for power with a view to determining the size of the initial stage of development in an eventual programme of construction.

The Columbia River

A further enormous potential supply of hydro power has been under study for ten years, by an International Commission, on the watersheds of Columbia and Kootenay rivers, which concern British

Fig. 3. Main features of the Yukon scheme: the dam on the Yukon (indicated at the top of the map) would divert the flow of the north-flowing Yukon into an extensive series of high-altitude lakes, lying to the south, affording immense storage and regulating capacity

Columbia, and the States of Washington, Idaho and Montana. With its source in Columbia Lake in the Windemere Valley, south of Banff, Alberta, the Columbia flows 165 miles north in a big loop before turning south and crossing the U.S. Boundary. At the most northerly point, in the loop, a projected 700 ft. high earth-fill dam would form a water reserve for Canada and at other sites between Mica and the border; in the United States this would boost the output of two existing power plants and two now being built, as well as at four additional sites, by almost 4 million horsepower.

The U.S. Government has to date spent some $1·8 billion in Pacific Northwest States on the Columbia to produce 3¼ million horsepower for industrial expansion. Over the next two decades, a further 12 million horsepower will be needed. Development of many of the sites are held up by controversies as to who shall build the plants, about water rights, or as to rival claims of conservation groups, fishing interests and mining companies.

U.S. wants the storage. The United States, apparently more aware than Canada of the value of this power, has recently come up with a non-government proposal to build the dam at Mica Creek, said to cost $250 million, at no expense to Canada, receiving compensation through an agreement to release the storage to U.S. plants further down the river on a specified schedule during winter months of low flow. Under this proposal, over 2 million horsepower would be available to Canada, while 1·5 million would accrue to the United States in their stations lower down the river, notably Grand Coulee, Dalles and Chief Joseph.

An alternative proposal has lately been put forward by Ottawa, whereby excess Columbia River storage during flood periods would be ponded behind Mica Creek dam and diverted through a tunnel near Revelstoke into the Fraser River, during periods of low flow, thus creating an additional potential of 4 million horsepower for British Columbia, without depriving U.S. plants on the Columbia of any flow they presently get from the Columbia.

Kootenay River

Another project under study by this Commission is the Libby dam site, Montana, on the Kootenay river. When the United States applied to the International Joint Commission for authority to build Libby, it offered to compensate British Columbia for the 300 million acre feet of water storage from the Canadian portion of the watershed, which would be backed up north of the border by the 150 ft. dam. British Columbia, however, sought assurance of a supply of power in return for these storage facilities, and negotiations were suspended when the U.S. Government withdrew their application a year ago. Alternative schemes are possible. Another storage site is available at Bull River, Canada, which, it is claimed, would give Canada 300 million acre feet of storage and 85,000 h.p. of its own.

Another possibility lies in building a dam across the upper Kootenay at Canal Flats, Canada, and so diverting the runoff from the upper watershed into the headwaters of the Columbia, where it would enhance the supply of power to both countries on the Columbia river plants, both present and future. Considerable study appears to be called for before the I.J.C is ready to settle the question.

Saskatchewan-Nelson System

Another major, though remote, source of water power for Manitoba exists on the Nelson River in the Northern part of the province, some 350 to 450 miles from Winnipeg. With a fall of some 700 ft. and a flow ranging between 140,000 maximum and 28,000 minimum, the Nelson has a potential of some 2 million horsepower under natural flow conditions. Some 250,000 h.p. of this total could be developed by diverting some of the flow of the Saskatchewan, main tributary of the Nelson, through Lakes Manitoba and Winnipegosis, under the "Dauphin" scheme, bringing power to within 170 miles of Winnipeg.

The possibility of economically developing this power is clouded, however, by the rival claim to Sasketchewan river water, for irrigation, by the provinces of Alberta and Sasketchewan. If the 4 million acre-ft. needed for full development of all projected irrigation projects were to be diverted for that purpose, Manitoba would stand to lose from 650,000 to

750,000 h.p. or more than is already developed on the Winnipeg River.

As water is a provincially owned resource, this question will have to be resolved by an agreement between the three provinces concerned, on a basis of compromise. The time is nearing when Manitoba will have to develop the Dauphin project or resort to building more expensive thermal plants. This problem of how to apportion the water between the three provinces is the most important and complex one in the field of resources management with which Canada is faced, and it cannot be solved on a piecemeal basis.

Canada's Competitive Position Strong

J. A. Fuller, President of Shawinigan Water and Power Co., divides Canada's potential power customers into three categories; (1) those for whom power is the most important element of cost; (2) those for whom low power cost may be outweighed by high costs for transporting raw materials to the factory and finished goods to the market; and (3) those for whom power cost is a minor element.

For those in the first category he believes Canada's competitive position remains excellent. Due to the need for power in secondary industries and in domestic consumption, such customers can afford to pay higher prices than can electro-metallurgical industries, for energy from U.S. power resources such as those in the Pacific Northwest. Thus industries for which cheap power is vital will continue to be attracted by Canada's more remote sites, particularly those at, or close to, tidewater.

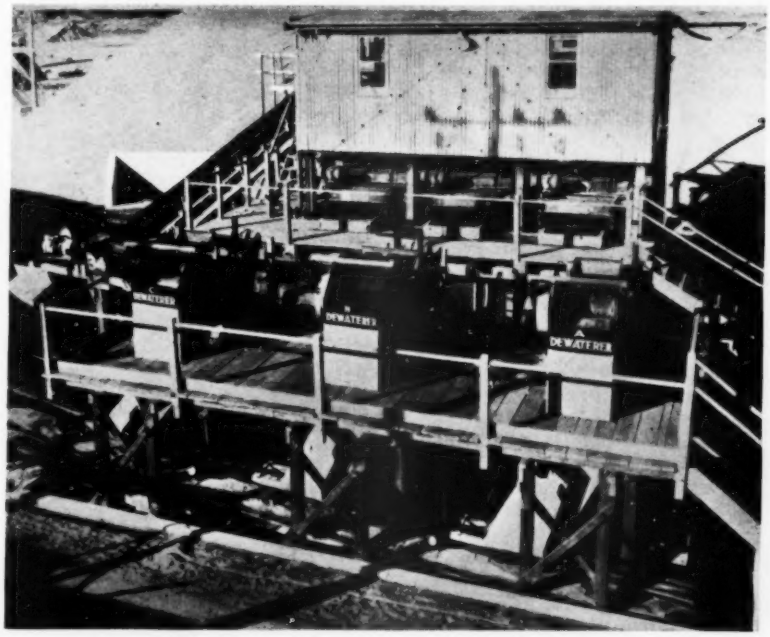
For industries in the second category he feels Canada's position to be less promising, especially for those industries whose products require processing with heat from thermal plants. In the third category, although power is a less important element, he believes that because Canadian energy will be priced lower, on the average, than in the United States, and because Canada's expanding economy invites secondary industries, Canada will continue to retain its good competitive position.

Aggregate Production for Warragamba Dam

The construction of the Warragamba Dam involving the pouring of 1,400,000 cu. yards of concrete requires approximately 2,500,000 tons of coarse and fine aggregate all of which is being supplied by the Sydney Water Board from its own aggregate winning and processing plant at McCann's Island. A gravel deposit near Penrith, known as McCann's Island, was selected as the most suitable site. This deposit, nearly 100 acres in area, is on the Western Bank of the Nepean River approximately 2½ miles downstream of the Western Highway Bridge.

McCann's Island is less than 20 miles by road and 12 to 13 miles direct from Warragamba so that there were no great transport difficulties. In order to produce the required 2,500,000 tons of aggregate about 3,750,000 tons of raw material have to be handled. After the removal of the excess sand in the form of overburden, the gravel-bearing deposit is revealed and can be worked. The building of the dam is based on a five years concreting programme necessitating the following rates: (a) Concreting three shift-days—50 cu. yards of concrete per hour; (b) concreting two shift-days—75 cu. yards of concrete per hour; (c) maximum concrete rate for larger blocks—three shift-days 100 cu. yards of concrete per hour.

The plant was therefore designed to feed aggregate to the ropeway at the rate of 170 tons each hour for three shifts daily. This rate will meet the maximum demand for concreting without having to resort to the limited storage in bins and stockpiles at the dam. This vast project required six radial boom-type stackers, 38 conveyors, six crushers, three classifiers, nineteen screens of which seventeen are of the well-known Pegson-Telsmith type, varying in size from 10 ft. x 4 ft. down to 6 ft. x 3 ft. and having triple, double or single decks as the process demanded at each particular stage. A general view of the plant is given in the accompanying photograph.



View of Warragamba aggregate production plant showing the 6 ft. × 3 ft. single-deck screens and dewaterers for minus $\frac{3}{16}$ in. product

The Sfindex Annular Jet Turbine

Now that the experiments on the Sfindex turbine have come to a definite conclusion it is possible to give a brief survey of the development. The author has been associated with this turbine as adviser on the technical tests, and as an expert called in corroborating the results obtained at certain stages of development.

By PROFESSOR HANS GERBER, E.T.H., ZURICH

THE axial, full-admission turbine of Jonval gave poor part load efficiency, which is hardly surprising in view of the mechanism used at that time for regulating the flow of water. Conditions were fundamentally improved when Girard, in about 1856, introduced the impulse principle. Thus for a few decades the Girard turbine was uncontested for medium and high heads until it was superseded by the Francis reaction turbine and the Pelton wheel. Since the turn of the century very few have been built.

With the progressive development of power schemes, the gap between the Pelton and Francis turbines became more and more noticeable. For specific speeds less than about $n_s = 60$ (metric) the efficiencies of Francis turbines were undoubtedly poor. The same applied to single-jet Pelton wheels above about $n_s = 30$. To bridge this gap 2 and 4-jet, and more recently 6-jet impulse turbines have been built, as for instance those at the Schwarzenbach scheme (1925) having three runners and six jets[1].

There was also no lack of attempts to fill this gap. The best known is the "vortex-flow" turbine of Reiffenstein[2]. The axial admission of an annular jet to an unshrouded runner was produced without any guide-apparatus other than a specially designed spiral casing. Under 2·5 m. head, the maximum efficiency of Reiffenstein's 2 h.p. model turbine reached 79·5 per cent. and the efficiency curve was very flat. However this turbine could not be successfully developed and, as far as is known, only low-power machines have been built.

As Reiffenstein himself pointed out, one of the main objects of the new design was not achieved, namely good efficiency in the specific speed range between 30 and 60. As soon as the full load value of n_s falls below about 100 such a decline in efficiency must be reckoned with, due to the thin annular jet, and the turbine is no longer of economic interest, particularly for large installations.

It appears that others were also engaged elsewhere in studies of a similar kind[3]. However details were not published at the time, presumably because of the unsatisfactory efficiency obtained. Also n_s was about 130, which was further confirmation of Reiffenstein's findings about the lowest attainable specific speeds for full-admission impulse runners.

In the early nineteen thirties a new development took place which made the existing gap rather less noticeable. Francis turbines were then built for higher heads, in 1939 the Bitto III scheme achieving a head of about 400 m. In Norway a machine has been running for some time under a head of about 420 m., and very soon the turbines of the Fionnay station in the Valais will be in operation under static head of 462 m. However the question whether Francis turbines are the correct solution for heads of between 400 and 500 m. has not yet been clearly resolved[4, 5, 6]. In these publications the relative advantages and disadvantages are outlined with particular clarity. However it appears from these articles that there will always be a need for an impulse turbine with a full-load specific speed as little as possible above 100 and having a flat efficiency curve with sufficiently high absolute values.

Preliminary Experiments

Whereas probably all types of turbine runners have until now been developed with the idea of obtaining the best possible admission of the water, in the following case it was the guide-apparatus that was the first thing to be investigated. Extensive studies and experiments were undertaken with the object of producing an annular jet with the following qualities: higher nozzle efficiency, uniform velocity distribution, and constant outlet flow angle over the widest possible range.

The stimulus for these investigations was provided by A. J. Schneider's proposals about possible forms of nozzle for giving annular jets, in which connection

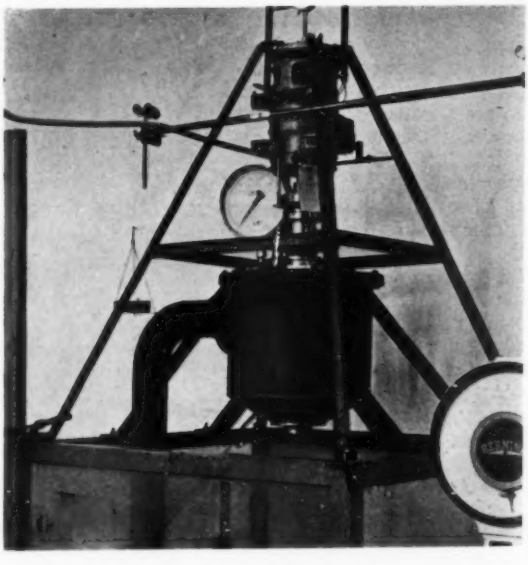


Fig. 1. Apparatus for testing nozzles to produce annular jets

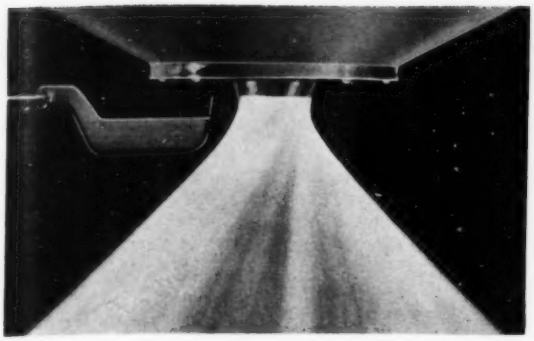


Fig. 2. View of typical annular jet produced with apparatus shown in Fig. 1

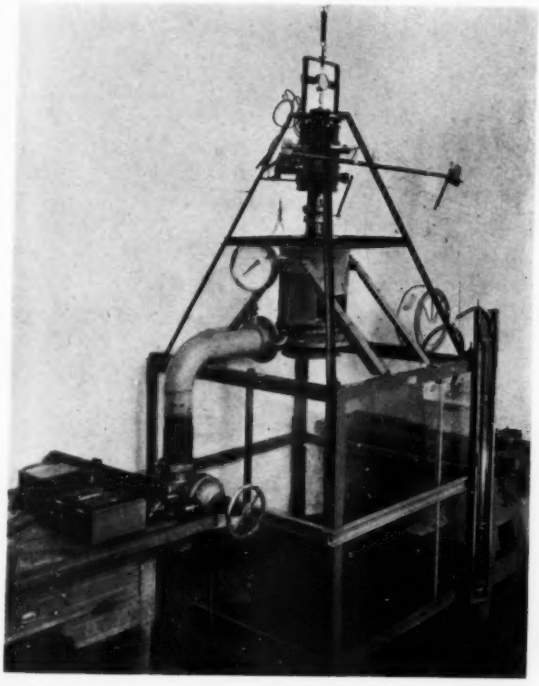


Fig. 3. Test rig in hydraulic machinery laboratory of the E.T.H., showing the smaller model turbine

the application to turbines was by no means the uppermost consideration in his mind. The models based on Schneider's ideas, however, gave unsatisfactory results, as did the first experimental runner which he developed.

It was at this stage of development that Messrs. Sfindex had, with their research staff, began investigations into a full admission axial impulse turbine. The experimental apparatus which was used is shown in Fig. 1. As a result of these tests various designs have been protected by patents[7] and in addition it was shown that the annular jets obtained could also be used for quite different purposes.

With this apparatus it was possible to produce annular jets of the required type and quality, Fig. 2 showing such a jet together with the pitot-tube used in the tests. It was just at this stage that runners were also developed, and Fig. 1 shows how their output was measured on a small D.C. dynamometer.

Small Model Turbine

The investigations showed that the swirl-chamber was unnecessarily large and therefore hardly suitable for high heads or large sizes of machine. A new small test turbine was therefore built with a normal type of spiral casing in which, by suitable means, the previously developed annular-jet nozzle was incorporated. The inlet diameter D_e of the spiral was made comparable in size with Francis turbines so that it could not possibly have an adverse influence on the formation of the annular jet. It is therefore by no means certain that the particular size of spiral chosen should be regarded as the optimum. The arrangement of this model turbine as tested by the Sfindex engineers in the Hydraulic Machinery Laboratory of the E.T.H. with the facilities available there, is shown in Fig. 3. In addition Fig. 4 shows schematically the test installation together with the simple and easily controlled measuring devices. With this test rig it was possible to carry out a large part of the development work. As a result, a runner was finally evolved which, with suitable nozzle combinations, gave a full load n_s of about 150. This result was unfortunately further confirmation of the correctness of the statement made by Reiffenstein that it was not possible for a full admission impulse turbine to have a specific speed less than 100 without an undesirable loss in efficiency.

Even so this small model tubine of scarcely 0·7 h.p., under 6 m. test head and with a representative runner diameter $D = 80$ mm., already gave an hydraulic efficiency of about 78 per cent. Tests at heads between 3 and 12 m. showed only a small influence of the efficiency. This result, together with the relatively flat efficiency curve and bearing in mind possible scale-up effects, was so encouraging that it was decided to proceed further with the work on a new basis.

Large Model Turbine

After considering the necessary size of such a

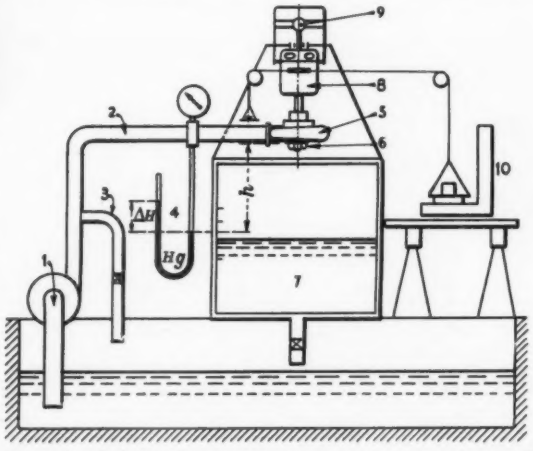


Fig. 4. Schematic arrangement of test rig and measuring apparatus for the smaller model turbine

1 Pump
2 Pressure supply pipe
3 Bypass outlet
4 Differential mercury manometer
5 Spiral casing
6 Runner
7 Measuring tank
8 Electric dynamometer
9 Tachometer
10 Balance

Fig. 5. View of test installation of the large model turbine at the Kubel power station

model turbine it soon became obvious that the facilities of normal laboratories would hardly be sufficient for this work. Remembering the manufacturing accuracy required for the runner, and bearing in mind the size of models used in existing cavitation rigs, a new reference diameter of 200 mm. was chosen. If, however, the test head was to be increased appreciably it would soon result in big flows and correspondingly large brake-horsepowers. Such a test rig could only be installed in a power-station under a natural head of water.

At this point sincere thanks should be expressed to the St. Gallen-Appenzell Power Company and particularly to the Director, Mr. U. Vetsch, for making it possible to install an experimental turbine of this size in the Kubel power-station. This enthusiastic cooperation in the research has contributed largely to the success of the present achievements. Thanks should also be expressed to Mr. Furrer, the station superintendent, and his staff at Kubel, who, with unflagging zeal, gave help wherever needed. Thus was the idea of a 250 h.p. model turbine under 80 metres nett head made possible. Fig. 5 shows the test rig connected to a pressure main at the Kubel works. At the end of the long straight pipe, just upstream of the turbine, a V.D.I. long-pattern venturimeter was installed for measuring the water flow. Despite its standard shape and careful installation, this was calibrated before the field tests were made. The venturimeter, together with all upstream and downstream piping, was checked against a volumetric tank in the Hydraulic Machinery Laboratory of the E.T.H.

Fig. 6 is a close-up view of the test rig. On the right is the inlet pipe leading from the venturimeter mentioned previously. Also on the right-hand side of the picture are to be seen the associated differential manometers, and the pressure gauge (with damping chamber) by which the pressure head was measured at a ring of static tappings upstream of the spiral casing.

Fig. 7. Annular jet without runner, large nozzle opening

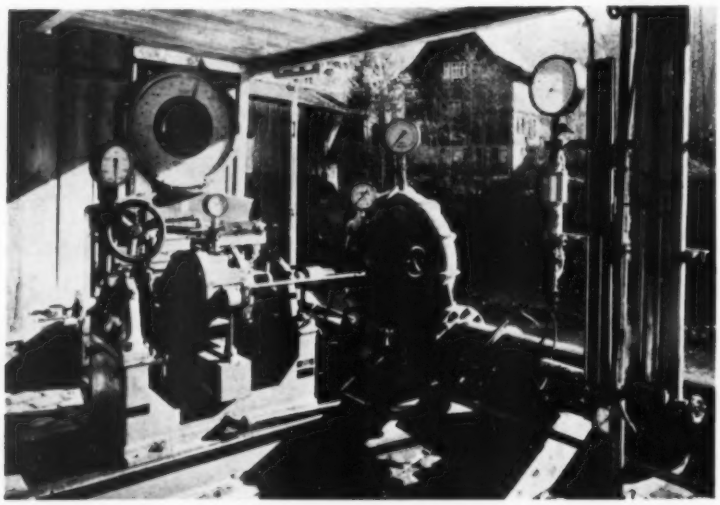


Fig. 6. Brake and measuring apparatus for the large model turbine at the Kubel works

The turbine is provided with double bearings to enable the hydraulic efficiency to be computed, a method which is used in all modern test rigs. In addition the hydraulic brake (from the Institute of Internal Combustion Engines of the E.T.H.) is also mounted on frictionless bearings. The fully automatic balance had already been graduated in kilogramme-metres torque and could be periodically checked, with the cooling water cock open, against calibrated weights. The exact rotational speed was obtained by timing a direct-coupled counting mechanism. Additional measurements were made with a precision hand tachometer. All the measur-

Fig. 8. Water discharging from runner, with large nozzle opening, and operating at a favourable rotational speed

ing gear was checked in every detail. The brake was remarkably stable and for practically constant head gave only slight speed variations. As a result the measured efficiency points deviate at the most by $\pm 0{\cdot}2$ per cent. only from the brake curve which was averaged each time. Steady conditions were always very quickly obtained so that, in a relatively short time, measurements could be made for a considerable number of settings.

Also seen in this illustration is the handwheel for adjusting the central body of the nozzle. The number of turns of this wheel is a measure of the jet-opening. The pressure in the top cover behind the central body was measured by the lower manometer, thus enabling the operating forces for the control gear to be calculated.

The water leaving the runner discharged back into the river channel. As a precautionary measure the rubble-faced side walls near the model turbine were protected with steel plates. Fig. 7 shows the annular jet issuing from the nozzle under a head of 80 m., without the runner in place. With the runner installed, the exit energy of the water discharging is quite small, with resulting good efficiency, as can be clearly seen in Fig. 8.

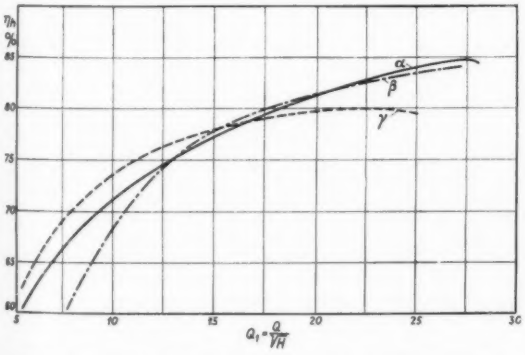


Fig. 9. Runner characteristics for various nozzle combinations

Survey of Model Tests

As always with such development work there were a number of special problems, in addition to those peculiar to the runner design, which had to be studied and, where possible, solved by appropriate tests. Some of the more important findings are briefly described in the following section.

Despite the preliminary tests already completed on the small model, it was decided to investigate the effect of various combinations of nozzle and runner. As shown in Fig. 9, the characteristics of the same runner can be considerably altered by these means. The distance between the nozzle mouth and the inlet edge of the runner is also important. This is different for each runner and moreover depends primarily, as would be expected, on the shape of the annular jet. From Fig. 10 it appears that a clearly defined optimum distance can be established. In this connection it was reassuring to find that the most favourable position of the runner relative to the nozzle is inde-

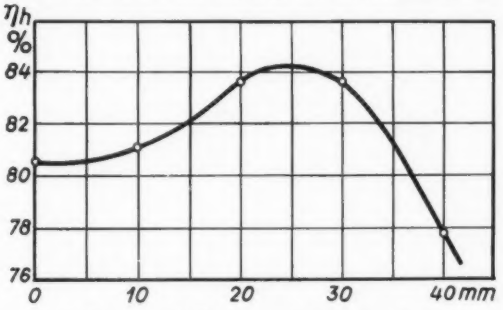


Fig. 10. Influence of distance between nozzle exit and runner

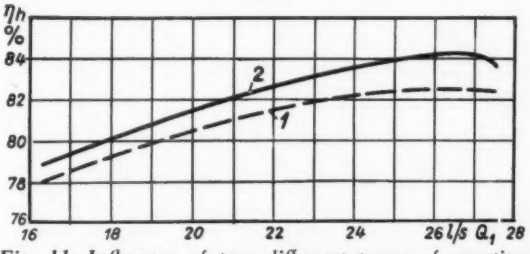


Fig. 11. Influence of two different types of aerating shield

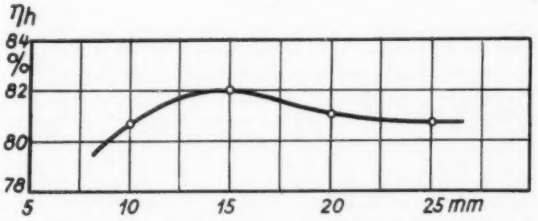


Fig. 12. Variation of efficiency resulting from changing position of aerating shield

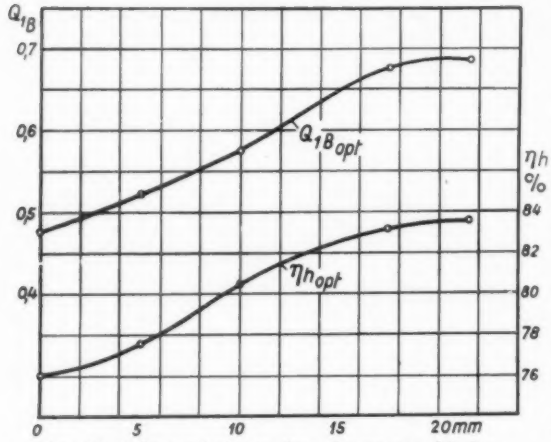


Fig. 13. Effect of shortening the runner blades

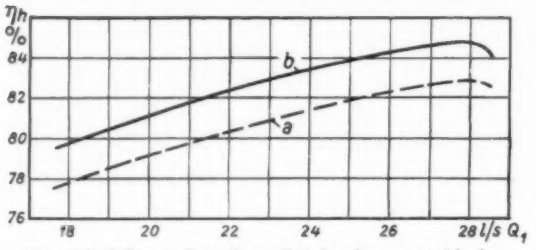


Fig. 14. Effect of surface finish of runner blades

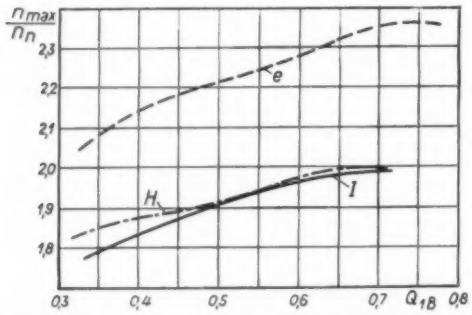


Fig. 15. Runaway speed n_{max} for different runners in terms of mean rotational speed n_n

pendent of model size and absolute head.

The aeration of the annular gap between the runner and nozzle proved to be of decisive importance. For this purpose various aerating shields were designed and tested. Fig. 11 shows the variation of efficiency for two different types of shield. The aerating shield has the job of preventing the water which leaves the runner from hindering aeration upstream of the runner. The position of this shield can certainly have a marked influence on efficiency, as Fig. 12 shows.

The effect of a systematic shortening of the runner blades was investigated, particularly in the case of type *E*. In Fig. 13 it will be seen that the efficiency tends to an optimum value at the higher rates of flow.

As for all other types of turbine, the degree of surface finish of the runner blades naturally has an important effect on efficiency. The curve *a*, Fig. 14, corresponds to Surface II of VSM*, and curve *b* to Surface III. It is interesting that the difference is constant for nearly all outputs.

Of great importance in addition to efficiency and power, is the maximum runaway speed n_{max} and its ratio to the best mean running speed n_n. This ratio for impulse and Francis turbines has always been about 1·8. The best runner *e* developed in the small model turbine was not altogether suitable in this respect as it had a ratio of 2·37. However, Fig. 15 demonstrates that with the two runners *H* and *I* of the larger model turbine this relative value was, at the worst, reduced to twice n_n, and usually even smaller ratios. From the strength point of view this ratio is already regarded as perfectly reliable for large generators.

Finally in Fig. 16 the efficiency curves of the three best large model turbines are compared. Runner *E* corresponds to the runner type *e* which was the best developed on the small model turbine. The improvement which was obtained with the two runners *H* and *I* is important and very gratifying. Efficiencies of 86 per cent. can thus be safely reached, despite a representative runner diameter of only 200 mm.

Fig. 17 shows the various runners tested in the small and large model turbines. This brief survey and comparison of results only cover a small portion of the many different test which were carried out. They indicate nevertheless that the Sfindex annular-jet turbine has been examined fundamentally and in as many directions as possible with the facilities and time available.

Model and Full Scale Efficiencies

Relatively little accurate information is available regarding the scale-up in efficiency of present day impulse turbines, and probably nothing is known about Girard turbines. As far as is known no such effects have been summarised in scale formulae, as has been done for reaction turbines. All that is usually said is that the well known formulae of Ackeret and Moody are not applicable, which is hardly surprising because these are, of course, intended only for reaction turbines. While the full-load efficiency of Pelton wheels usually corresponds more or less directly with that of the model, a remarkable scale increase occurs, chiefly at very low loads, which is very much greater than is predicted by either of the above formulae. These facts were too well known for there to be any likelihood of applying any of these formulae to the Sfindex turbine.

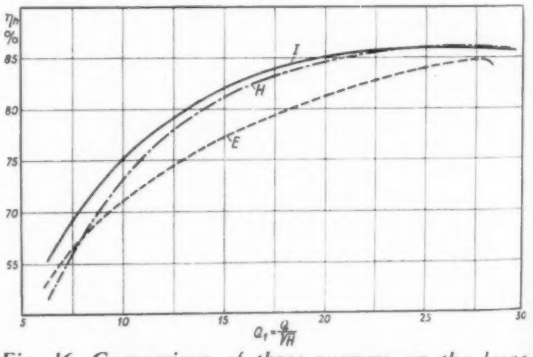


Fig. 16. Comparison of three runners on the large model turbine

E: $n_1 = 270$ r.p.m.; *H*: $n_1 = 265$ r.p.m.; *I*: $n_1 = 256$ r.p.m.

* VSM = Swiss Machine-Tool Association.

Fig. 17. Different runners tested on the large and small models

However, the two exactly similar test turbines, equipped with the same types of runner *e* and *E*, now provided a perfect opportunity of verifying the scale relations for this new type of turbine. Information supplementary to Fig. 18 is listed in Table 1.

TABLE 1

Model turbine	Small	Large
Runner type	*e*	*E*
Index	*k*	*g*
Reference diameter *D*	80	200 mm.
Test Head *H*	6	80 m.

The first of the formulae published by Moody usually gives slightly optimistic full-scale values. It is used to scale up curve 3 from curve *e* in Fig. 18, and is written

$$\eta_g = 1 - (1 - \eta_K)^4 \sqrt{\frac{D_K}{D_g}}$$

Similarly the Ackeret formula, which is usually characterised as conservative, has been applied to compute curve 4, and is written

$$\eta_g = 1 - \tfrac{1}{2}(1 - \eta_K)\left(1 + \sqrt[5]{\frac{D_K\sqrt{H_K}}{D_g\sqrt{H_g}}}\right)$$

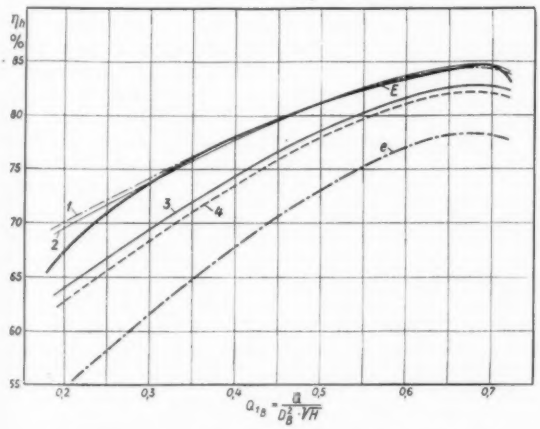


Fig. 18. Verification of scale-up formulae (see text for notation)

As can be seen, both formulae give nothing like the scale increase between curves *e* and *E* for similar runners in the small and large turbines respectively. A thorough investigation showed conclusively, however, that the relation between the two curves *e* and *E* could be predicted with surprising accuracy by another formula, namely that of Gregorig[8] which is written

$$\eta_{hg} = (1 - K_{v2}^2) - [1 - K_{v2}^2 - \eta_{hk}]\, i\sqrt{\frac{Re_K}{Re_g}}$$

By comparing curves *e* and *1* and calculating backwards using the exponent $i = 4$ suggested by Gregorig a value of $K_{v_2} = 0{\cdot}245$ is obtained for the runner exit velocity (in the analagous case of the Sfindex turbine this had to be substituted in place of the draft-tube exit velocity coefficient K_{v3}). Good agreement is obtained over the wide range from 100 per cent. to about 45 per cent. of the full-load flow.

Further investigations and comparative calculations have, however, revealed that $K_{v_2} = 0{\cdot}245$ is slightly high; the value $K_{v2} = 0{\cdot}20$ may give better agreement with practice. Another point is that the exponent $i = 4$ applies for closed conduits (i.e. flowing full),

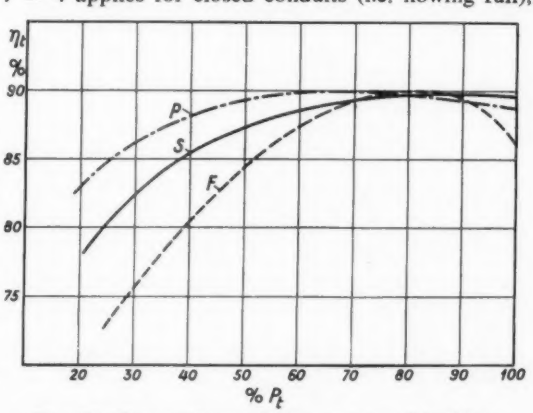


Fig. 19. Comparison of three types of turbine

P Four-jet Pelton wheel
F Francis turbine
S Sfindex annular jet turbine

whereas in the Sfindex turbine free surfaces must be assumed in the runner passages, and the calculation can be improved using $i = 5$. These two new assumptions yielded curve *Z* which represents the trend of curve *L* even more closely than curve *I*.

There is now undoubtedly good justification for applying the Gregorig formula, thus modified with $i = 5$ and $K_{e_2} = 0{\cdot}20$, to other model runners of the Sfindex turbine which have all been built on the same principle. Moreover, from the results on the large model turbine, it is now possible to make a sufficiently reliable estimate of the expected efficiencies of full-scale machines at any heads and flows.

Future Prospects

As with all such new designs, one should exercise a certain reserve when assessing possibilities for future applications of the Sfindex annular-jet turbine. There are, from experience, qualities and aspects which can only be correctly interpreted after long service under working conditions. The simplest way of appreciating the characteristics to be expected is by means of a numerical example. The following comparative calculation is based on a case from actual practice:

The efficiency curve has been measured on one of the high head Francis turbines of the Rodund power station[9]. If this curve is used for a turbine of Q = 12·4 cu. m. per sec. under the same head (H = 346m.) it gives a rotational speed of 600 revs. per min. for the same specific speed, and the curve *F* of Fig. 19. For the same conditions a four-jet impulse turbine with a bucket circle/jet diameter ratio m = 11·2 gives only 300 r.p.m. (curve *P*).

After scaling up with the Gregorig formula, method 2 of Fig. 18, the annular-jet turbine with runner type *I* of Fig. 16, gives the curve *S*. This lies between the other two curves *P* and *F* and is a little closer to *P*. This turbine, however, reaches a speed of 1,000 r.p.m. As the following table shows, from the point of view of overall dimensions, it also gives very favourable exit conditions.

TABLE II

Turbine-type	Pelton	Francis	Sfindex
Curve in Fig. 19	P	F	S
Water-flow Q ..... cu. m. per sec.	12·4	12·4	12·4
Head H ..... m.	346	346	346
Full load efficiency ..... per cent.	88·8	86·2	89·6
Full load power P_T ... h.p. (metric)	50,800	49,350	51,300
Normal speed n_n ... revs. per min.	300	600	1000
Runaway speed n_{max} revs. per min.	540	1080	2000
Speed ratio	1·8	1·8	2·0
Specific speed n_s	45	89	152
Runner reference dia. ..... m.	2·45	1·90	0·95
Supply pipe dia. ..... m.	1·45	1·15	1·20

It is thus apparent that the Sfindex annular-jet turbine gives an efficiency curve in between the other two types; it requires by far the smallest runner, and a spiral casing similar in width to the Francis turbine but appreciably smaller in overall dimensions. Thus it will undoubtedly result in a considerable saving in weight.

The much higher rotational speed will lead to a cheaper form of generator despite the somewhat higher runaway speed. With the smaller external dimensions of the machine, the size of the power house can also be correspondingly reduced. On the other hand, a disadvantage is the considerable height above tailwater. If, in the case cited, this is assumed to be 1·5-2·0 m., it will result in a loss of about 0·5 per cent. in the efficiency of the unit, similar in fact to the Pelton wheel.

From the constructional and manufacturing viewpoints the annular-jet turbine should not raise any particular difficulty. As already mentioned, mechanical solutions for the type of regulation and its components already exist. This also applies to the speed control and the pressure regulator for quick shut down. On the other hand the results from full-scale machines must be awaited before it can be seen how the turbine behaves under operating conditions—in particular how much erosion is caused by water, material in suspension, etc. It would thus obviously be of great interest if the construction of a few full-sized units were to be undertaken.

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Improved Rear-Dump Wagon

To meet the need for an increased capacity haulage unit in the size powered by the model C Tournapull, LeTourneau-Westinghouse Company, Peoria, Ill., U.S.A., announce that the capacity of their new model C rear dump wagon has been increased from 18 to 22 tons. The struck capacity of the new unit is given as 14.7 cu. yards, and 17 cu. yards when heaped. This greater load-carrying capacity has been obtained by increasing the inside width of the wagon body by 10 in. at the top and the top length by 2 in.

Overall length of the entire machine in the travelling position is now 30 ft.—9 in. longer than the previous model, while the wheelbase in the same position is 16 ft. 4 in., an increase of 6 in. The width of the vehicle, from centre to centre of tyres, is now 9 ft., which is $8\frac{7}{8}$ in. greater than before. Ground clearance is 22 in. As this is a decrease of 8 in., greater stability is ensured.

Some changes in reinforcements have been made to the new model, which is designed to be loaded by shovel, dragline or other types of auxiliary loading equipment. Equipped with constant mesh transmission, the vehicle weighs 42,690 lb., while with sliding gear transmission the weight is 42,440 lb.

Among other components which have not been changed are the four 21.00 × 25 24-ply tyres on which the wagon is mounted. A maximum turning angle of 90 degrees left and right is possible and multiple disc air brakes are provided on all four wheels; the total braking surface area is said to be 3,763 sq. in. Forward speeds with constant mesh transmission range from 2.5 to 29.2 m.p.h., while, with sliding gear transmission, 2.9 to 30.2 m.p.h. is obtainable at an engine speed of 2,000 r.p.m.

Book Reviews

Flood Control Journal. Issued by the Economic Commission for Asia and the Far East (ECAFE), Bangkok, Thailand. 90 pp.

This Journal, published under the auspices of the United Nations, gives an account of studies which have been conducted on the development of water resources, the greater emphasis being placed on river control from the viewpoints of water conservation for irrigational purposes and the prevention of damage rather than the generation of hydro-electric power. Power generation does, however, come into the picture when the circumstances permit the planning of a multiple-purpose scheme. The contributions cover the progress that has been made in regard to various schemes in India, Pakistan, Ceylon, China, Japan and New Zealand, and such topics as artificial rainfall, the relation between the different objectives in planning multiple-purpose schemes, canal seepage determination and appropriation of costs, together with a section dealing with fairly recent items of news.

Schleusen u. Hebewerke (Navigation Locks and Lifts). By Dr. Ing. Hans Debnert, Consulting Engineer and Professor of Transport Systems, Dresden High School. Published by Julius Springer, Berlin, and distributed in the United Kingdom by Lange, Maxwell & Springer, Maxwell House, 24, Marylebone Road, London, N.W.1. Price £3 18s. 0d. (cloth bound). 340 pp. with 320 ff.

In recent years navigation locks have become a feature of waterpower schemes on main waterways such as the Tennessee River and the Rhine and the Rhone. Although much information is scattered through American and European literature, it is difficult of access for quick and co-ordinated reference, and consequently the German handbook under review may be welcomed by hydro-electric engineers because it provides a comprehensive treatment of the design and construction problems involved. The book opens with the principles and essential elements of various types of navigation locks, filling and emptying systems and the conditions for their application. For those interested in the civil engineering phases of lock design and construction the descriptive matter and numerical examples admirably treat such questions as: (1) Dimensions and general arrangement of essential components, including locks with side chambers; (2) traffic capacity and locking time; (3) upstream and downstream approaches; (4) the forces imposed on walls and floors by earth and ground water pressures and during emptying and filling operations; (5) lock walls and floors of timber, reinforced concrete and composite concrete and sheet piling construction; (6) concreting technique including mixture design, placing and sealing.

On the structural and mechanical side valuable data on typical and special designs with their limitations are given concerning: (a) Lock gates and their components such as bearings, hinges, anchorages and sealing; (b) determination of gate loadings and forces on structural components; (c) operating forces and operating mechanisms; (d) construction and operation of control valves for filling and emptying systems; (e) accessory equipment; (f) lock operation and maintenance; (g) ship elevators.

Model tests have made important contributions to lock design and a systematic approach would have added value to the passing references to them concerning determination of satisfactory locking conditions, hauser forces, phenomena accompanying filling and emptying operations and their effect on vessels in lockage.

The book is adequately indexed and abundantly illustrated with typical examples of lock construction supplemented by tabulated statistical data and a comprehensvie bibliography classified under the headings of waterways, locks, lock construction and special literature cross referenced with the text to emphasise particular points.

O'Sullivan Dam. Technical Record of Design and Construction. Issued by the United States Department of the Interior, Bureau of Reclamation, Denver, Colorado. 1954. 60 pp.

This dam, which is of the zoned rolled-earth fill type, forms part of the huge Columbia Basin project and controls a drainage area of 4,000 sq. miles. It has a crest level of 160 ft. above streambed, is 19,000 ft. long at the crest, and has a volume of about 7¾ million cu. yards of fill.

The record, which is fully illustrated, gives a detailed account of the investigation work which preceded the construction, of the design considerations, and of the administration of the contract. The constructional methods are also discussed, and an interesting account is given of the painstaking testing work that was done to secure accurate supervision of all the materials used in the dam structure and incidental spillway and outlet works. There is also a summary of the costs involved.

Canadian Water Resources. Obtainable upon application to the Chief, Water Resources Division, Department of Northern Affairs and National Resources, Ottawa 4, Ontario, Canada. Price $3.00.

The Water Resources Division has now published Volume 109 of the Water Resources Papers, Surface Water Supply of Canada. This report contains run-off data for the climatic years 1949-50 and 1950-51 for the Arctic and Western Hudson Bay drainage division and for Mississippi drainage in Canada, which cover the whole of the Provinces of Manitoba, Saskatchewan, and Alberta, and of the Northwest Territories, as well as some adjoining areas in western Ontario and northeastern British Columbia. The data presented are the results of the hydrometric operations which were carried out in these drainages during the period October 1, 1949, to September 30, 1951, largely by the Water Resources Division, although operations were facilitated by active co-operation received from provincial authorities and from a number of private agencies.

This report includes a short description of the organisation and scope of operations, an explanation of the method of tabulation, together with stream-flow and water-level data, and meteorological data pertaining to the operation of evaporation stations. The appendix contains a reference list of hydrometric records for these drainage divisions, a list of available Water Resources Papers, and an index to the current issue.

Holman Dryductor Developments

We recently paid a visit to a Sussex gypsum mine to see a demonstration of the latest improvements in the Dryductor system of rock drilling developed by Holman Bros. Ltd., Camborne. This firm began investigations in 1945 on a system that would secure dustless drilling in dry, or reasonably dry, rock without the use of water, the objective being to suck the chippings by vacuum through a hollow drill steel. This procedure, it was foreseen, would not only prevent even the finest dust from escaping into the atmosphere, but would increase drilling speed by presenting a continuously cleaned face to the bit and would obviate the necessity to blow out the sludge from a wet-drilled hole before it could be charged. Preliminary experiments in which the chippings were withdrawn from the hollow drill steel through a side hole near the shank showed that the speed of dust withdrawal was insufficient to keep pace with that of drilling, so that the drill performance was hampered. This was overcome by designing a special drill having a central tube so that the chippings followed a straight-through passage from the drill bit to the hose attached to the back of the machine. The hose led to a portable cyclone-type dust collector, the vacuum being generated by a fan. This " Dryductor " system, as it was called, was developed as a practical equipment in 1950 and was described in our July 1951 issue.

Fig. 1. Dryductor drilling vertical hole for roof bolt

In the light of experience gained since that time, in which the soundness of the principle has been established, important improvements have been made in both the drill and the dust collector. The original Dryductor drill gained its special feature of dust extraction at some sacrifice of drilling performance, but a new design, shown in section in Fig. 3, is now available in which this drawback has been remedied. The new drill is shorter than its predecessor and weighs only 55 lb. as against 60 lb. Its drilling speed is stated to be superior to that of the Holman SL200, and, indeed, the only drill in the Holman range with a better performance is the new Silver Three, described in our June 1954 issue. As will be seen from Fig. 1, an anvil block is incorporated to maintain an unbroken passageway for dust, but the improvement in performance has been obtained by providing a lighter and faster piston blow. The piston diameter has been increased from $2\frac{3}{4}$ in. to $3\frac{1}{4}$ in. and the stroke decreased from $2\frac{1}{4}$ in. to $1\frac{5}{8}$ in.

As in the previous design, the drill is well vented to prevent any leakage of compressed air from impairing the vacuum in the central tube. In the new drill, however, part of the exhaust is conducted round the chuck end of the drill so that this region remains hand-cool after continuous working. In cases where oil is carried in from an oil bottle by the compressed air, this arrangement also ensures that the chuck end is lubricated.

The drill can be used without modification with an airleg or a stoperleg, each of which can be supplied in a range of sizes and in single or double telescopic form.

The drill steels are plain shanked and are either of the Holsteel tungsten-carbide-tipped type or are

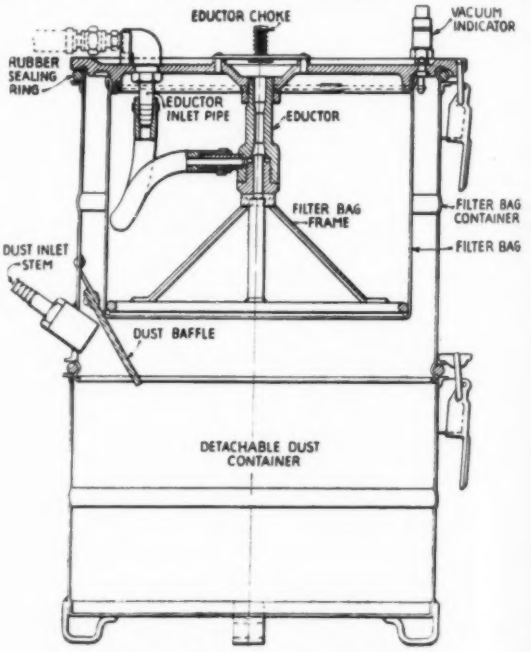


Fig. 2. Section through collector

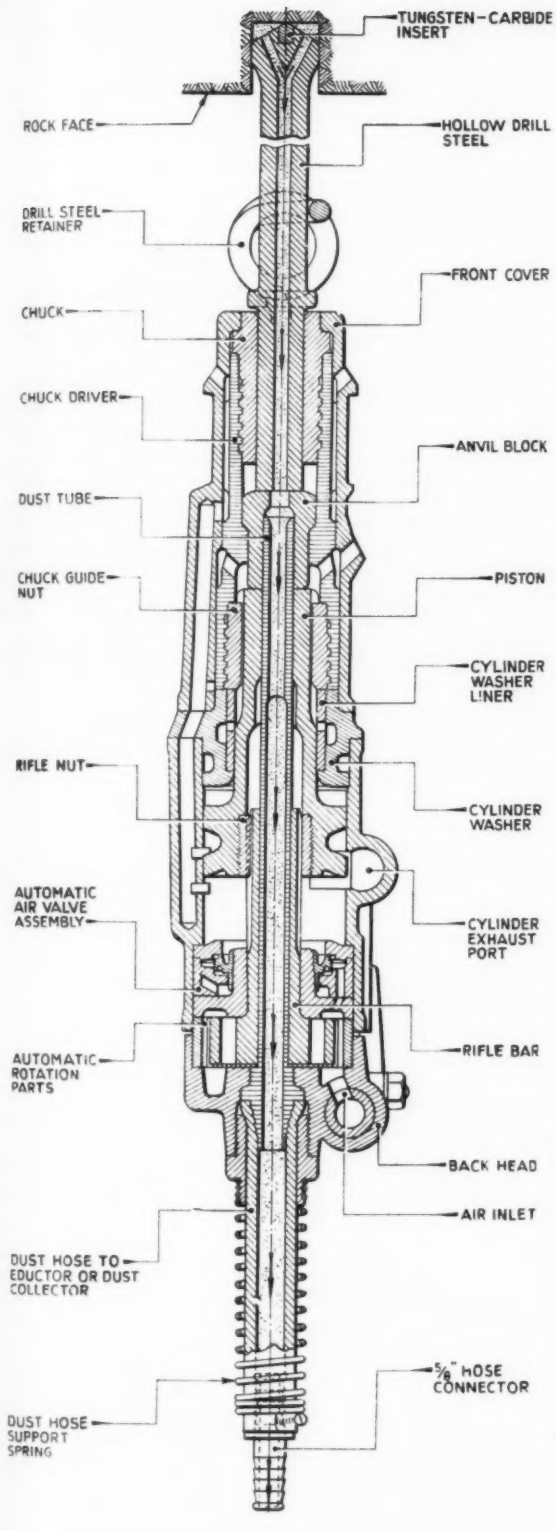


Fig. 3. Section through drill

fitted with tungsten-carbide Holbits. Cross bits are preferably employed, although chisel-type bits can be supplied. Stock sizes range from $1\frac{5}{16}$ in. to $1\frac{3}{4}$ in. diameter. The cross bits have four holes, which are located between the four wings, and the chisel bits two, leading to a $\frac{3}{8}$ in. central hole in the steel. The holes in the bits are of such a size that any chippings passing through them will clear right through the system. The side flutes formed in bits used for wet drilling are undesirable, and the bits normally used are circular when viewed end on.

The dust collector, shown in section in Fig. 2, has undergone major redesign. The vacuum is now maintained by an eductor fed by compressed air, and the incoming dust strikes a sloping baffle which throws all the but the lightest particles down to a removable container at the bottom of the collector, the lighter particles being arrested by a large bag filter in the upper part of the collector. This filter can be cleaned whenever desired by pressing a plunger on the top of the collector a few times; this reverses the air pressure on the bag and imposes a concertina action upon it. When the bottom container is full it can be removed in a few moments by undoing four toggle clamps, a cover is clamped on it, and a spare container is fixed to the collector.

In the latest design of collector, as seen in Fig. 2, the air eductor has been completely redesigned to give improved performance and reduced air consumption. It is also readily taken adrift for cleaning.

A vacuum gauge can be fitted to the collector, but a special indicator can be supplied, having a red button which must be drawn down out of sight before the operator starts to drill.

The demonstration to which we have referred showed the equipment applied to roof, wall and floor bolting, and incidentally exhibited the usefulness of the Holman impact wrench (see our July 1954 issue) for rapidly tightening a nut to a controlled torque of 200-250 lb. ft., or if need be, for removing it. A complete cycle in which a hole was drilled in a shale formation and a 3 ft. wedge-type roof bolt was driven and bolted up was timed at 2 min. 31 sec. We understand that in a Pennsylvanian coal mine a record was set up by placing thirty 4 ft. roof bolts in 68 mins., using a single drill.

The new drill has received a certificate of approval for use underground from the United States Bureau of Mines after tests conducted in the Bureau's test mine at Pennsylvania.

Dryductor equipment is available in the United States from The Goodman Manufacturing Company, Halsted Street and 48th Place, Chicago 9, Illinois, U.S.A.

Metrovick Electrodes. A conveniently-sized Pocket Electrode Guide, neatly indexed, has been issued by Metropolitan-Vickers Electrical Co. Ltd., and specifies the various types of electrode they manufacture. Particulars such as the identification and application of an electrode are given, together with operational details, mechanical properties, deposit analysis, deposit rates, etc. An explanation is also given of electrode code numbers and there are tables for temperature conversions, wire gauges and their equivalents in inches and millimetres, and for hardness number conversions.

Abstracts from the World Technical Press

Run-of-River Plant Research

This paper discusses the results of investigations made at the Theodor-Rehbock river-works laboratory of Karlsruhe Technical University. These results are essentially based on tests made with a 1·30-scale model of one of the Main River power stations and

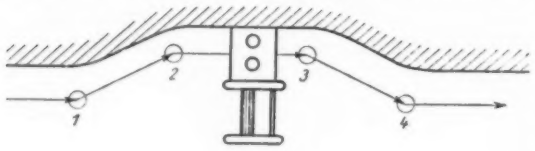


Fig. 1

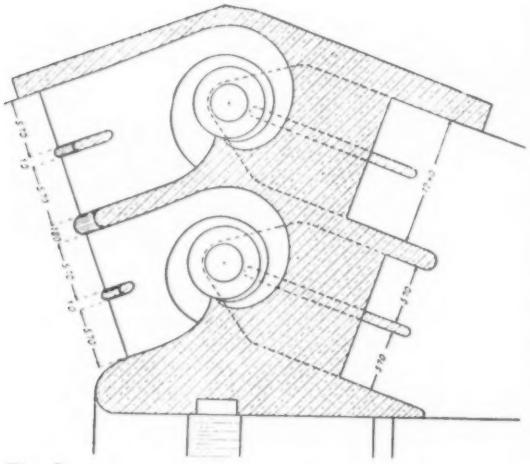


Fig. 2

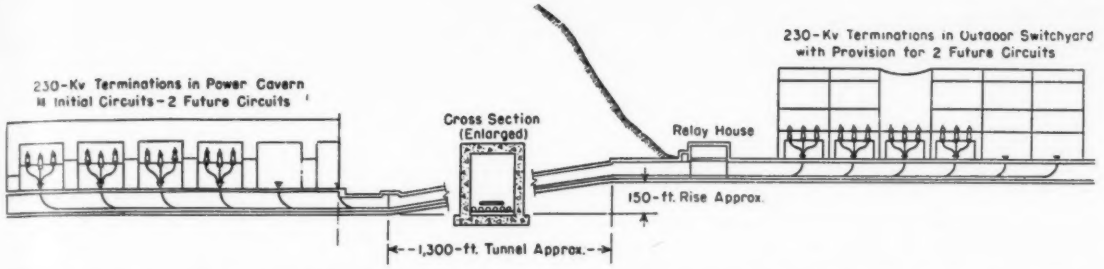
also takes into account model tests relating to other existing plants. The fundamental layout of the barrage, power house and lock of a plant set up on a navigable river is considered in three positions, in all of which the power house is erected in a recess cut in the bank of the river, but sited respectively in relation to the axis of the barrage, upstream, level and downstream. There follows an investigation of the flow approaching the power house of the most favourable shape of the pier separating the power house from the barrage, of the influence of the trashrack, the transition of the river bed to the intake sill, the pattern of the forebay, and of the sill that is frequently provided between pier and forebay. A third section deals with the shape of the pier on the tailwater side, the discharge of drifting material into the afterbay, head losses at the power house, and layout of the afterbay. The paper concludes with short considerations on the hydraulically most advantageous design of the power house. The authors underline the head losses resuting from the fourfold diversion of the flow (Fig. 1) and suggest the layout shown in Fig. 2 as ensuring the best pattern of intake (angular approach) and discharge flow. In the authors' words, this design is not intended as a complete solution of the problem, as it applies only to purely the hydraulical requirements and more particularly aims at checking continuous head losses, while constructional considerations are left aside. (Prof. Dr.-Ing. H. Wittmann and Dr.-Ing. G. Garbrecht, *Die Wasserwirtschaft*, Vol. 45, No. 2, Nov. 1954, p. 33, 6 pp., 18 ff.)

New Prospects for Low-Head Developments

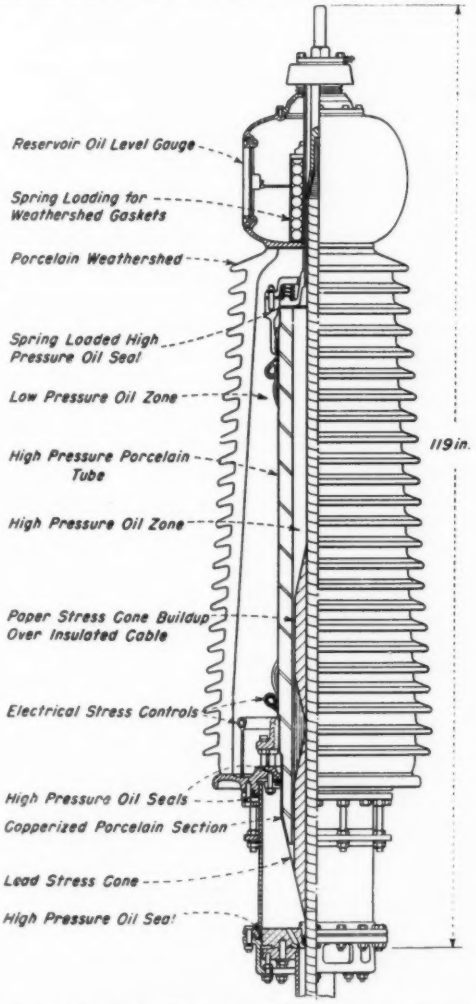
In this article, the author deals with the submerged monoblock units of the Castet power station, as briefly described in WATER POWER, October 1954, p. 403, and discusses the prospects offered to low-head developments by this novel type of generating unit. Electricité de France is now endeavouring to solve the problem of small plants incorporated in barrages set up for regulating the flow of rivers passing through flat, open country. There are in France thousands of such dams which, although generally less than 2 m. in head, represent a considerable source of energy. The designers of the Société Neyrpic have had the idea of topping existing barrages with siphons enclosing a unit quite similar to the Castet sets, though smaller in size; underpinning work would thus be reduced to a minimum, and a simple apparatus priming and unpriming the siphon would do away with the gate-controlled gear for starting and stopping the generating units. An installation of this type has been put into service by EDF some months ago at the Maignannerie power station on the river Mayenne; not only does this installation give unrestricted satisfaction, but the economies achieved in constructional costs were rather better than expectation, and there is now every reason why this new conception should find a general application on other open-country rivers. As to larger units, a substantial amount of preparatory study still remains to be done but it is now firmly established that units up to three times the size installed at Castet can be built; besides, thanks to this larger size, the civil engineering work could be considerably simplified compared with Castet. The open-work barrage, developed to the point of a skeleton structure only and closed by the generating sets and the gates, is now well within the scope of present possibilities. The way would thus seem to be open to run-of-river developments free of any diversion works and relieved of the difficult operation of cutting off the flow. These new prospects extend, of course, to tidal development on the lower courses of French rivers and in the Mont Saint-Michel Bay. (J. Guimbal, *Le Génie Civil*, Vol. CXXXI, No. 17, 1.9.1954, p. 321, 4 pp., 5 ff.)

A 230-kV Pipe-type Cable

A description is given of the 230-kV oil-filled pipe-type cable connecting the unit transformers of the Cubatao underground power station, through a 1,500 ft. tunnel, with an outdoor switchyard from which the city of Sao Paulo is supplied. In Brazil, power and other utility services are provided by operating subsidiaries of the Canadian corporation Brazilian Traction, Light and Power Co. Ltd. in an area in the south-east which, though small, contains 50 per cent. of the installed generating capacity of the whole country, and produces more that 60 per cent. of the electrical energy consumed in Brazil. The main characteristics of the cable are as follows: 61 hard-



drawn copper strands, each 0·0905 in. dia; insulation thickness 0·835 in., including 3 metalised paper tapes; plain lead sheath 0·078 in. thick; electric welded pipe 8 in. in overall diam. and of 0·25 in. wall thickness, shot-



blasted inside and finished with a coat of rust-resistant paint. The outside finish includes shot-blasting and a coat of coal tar enamel. The potheads selected are of the dual porcelain tube type, the smooth inner tube confining the oil at high pressure, and the corrugated outer tube acting as a weathershed and containing oil at atmospheric pressure. Because of the distance from the insulating oil supply, operating and maintenance regulations stipulate that a supply of oil sufficient to fill the pipe always be available. (S. T. Franks, Canadian-Brazilian Services Ltd., Toronto, *Electrical World*, Vol. 142, No. 22, Nov. 29, 1954, p. 76, 5 pp., 5 ff.)

Assembly-Line Methods at McNary Dam

When the McNary power station began feeding power into the Bonneville Power Administration's transmission system on November 6, 1953, a full 30 days ahead of schedule, it was expected that the plant's full rated capacity of 980,000 kW would be reached late in 1956. Delayed deliveries of material and equipment, due to the Korean war, the allocation system of the Defence Production Act, and strikes, impaired the progress of work to such an extent that the " unit-every-90-day " schedule lagged behind by as much as 16 months. This prompted the Army Corps of Engineers to introduce " assembly line " procedures for the installation of the remaining sets. The programme worked out to co-ordinate the work of the various contractors and to speed up the delivery of turbine and generator parts, and other heavy materials, has stood the test, and generator 4 went on the line in June, only 15 days behind schedule. Generator 5 will be put into operation on time, and generator 6 ahead of schedule. Units 7 to 12 inclusive are under completion, and it is expected that they will be delivered ahead of schedule to an increasing extent, amounting probably to two or three months. When generators 5 and 6 go on the line, 140,000 kW rated capacity will be added to the north-west power grid for meeting critical winter needs. (*Electrical World*, Vol. 142, No. 9, 13.9.1954, p. 16, 4 pp., 7 ff.)

Flow in Ski-Jump Spillways

Ski-jump spillways which evacuate flood water over the roof of a power house leaning against the downstream face of a dam are now a common feature in French hydro-electric developments. This article, written by two engineers of the EDF Hydraulic Research Department, analyses some of the characteristics of the flow at the downstream end of this type of spillway. The question is first examined theoretically, proceeding from the study of the nature of the flow in surface spillways, the way it varies in function of the discharge, and the influence of these variations on energy production. The tests carried out at the St.-Etienne-Cantalés and Chastang plants, and the methods of measurements applied are then described. In the final section of the article the authors discuss the evolution of the boundary layer on the apron of surface spillways, and compare theoretical and experimental results, as well as head losses occurring in the channels of these spillways. (R. Maitre and S. Obolensky, *La Houille Blanche*, Vol. 9, No. 4, July-August 1954, p. 481, 31 pp., 42 ff.)

Macedonia's Energy Potential

The possibilities of hydro-electric development in Macedonia are reviewed. Power-water resources in the country are abundant but have so far been developed to a really negligible extent. Economically utilisable resources are assessed, in terms of power, at 590 MW, and the average yearly production at 4,160 million kWh. At the present moment the aggregate installed discharge does not exceed 26 cu. m. per second and the plant in course of construction on the Mavrovo River is designed to absorb no more than 8·7 cu. m. per second, while 558 cu. m. per second are still untapped. The general topography of Macedonia lends itself extremely well to the setting up of hydro-electric plants, and medium-height dams can be built on almost every river. Tomo Marinov, Skopje, *Elektrotehniski Vestnik*, Vol. XXII, No. 7/8, July-August 1954, p. 229, 7 pp., 4 ff.)

Roanoke River Project

It will be remembered that this project was the centre of a long and bitter dispute between public and private power interests, the Supreme Court ultimately ruling in favour of the Virginia Electric and Power Company. Construction at Roanoke Rapids, N.C., is now progressing at a swift pace, and concrete pouring on the 100,000 kW power house and the 3,000 ft. long dam has reached the midway point, while only about 30 per cent. of the 8,000 ft. tailrace awaits completion. The tailrace is being cut from solid rock to a maximum depth of 56 ft. and a minimum of 51 ft., the channel being 80 ft. wide. The cut for the tailrace is ranked as one of the largest ever made in the U.S. When completed, the dam will have absorbed 250,000 cu. ft. of concrete. The power house is being erected in a 70 by 230 ft. hole carved to a depth of 72 ft. out of granite. *(Electrical World*, New Issue, November 22, 1954)

Water Power in India

A special double issue of the undermentioned journal is devoted to the activities of the Central Water and Power Commission (CW&PC) of the Irrigation and Power Ministry. Questions related to hydro-electric development are dealt with in the following articles:—

Developing India's Water and Power Resources, by Kanwar Sain, chairman of CW&PC, p 37; Power Development in India, by M. Hayath, p. 39; Designs Organisation and its Functions, by H. L. Vadera, p. 40; Water Resource Utilisation in India, by R. D. Dhir, p. 49; Role of Hydrology in Project Planning, by P. R. Ahuja, p. 53; Role of Power Wing in the CW&PC, by H. S. Kulkarni, p. 57; India's Hydro-electric Resources and their Assessment, by K. L. Vij, p. 63; Power Transmission and CW&PC Activities, by V. Venugopalan, p. 68; River Valley Projects and the CW&PC Research Station, by D. V. Joglekar and V. N. Nagaraja, p. 70; Organisation for Water and Power Development, Editorial, p. 91. *(Indian Journal of Power and River Valley Development* Vol. IV, No. 6/7, June-July 1954, 90 pp., many ff.)

Empirical Rating of Current Meters

The very widespread use of the hydrometric current meter does not conceal the fact that, in spite of apparently easy handling, many precautions and the utmost care must be taken if the results obtained are to be considered accurate and applicable in practice. A correct rating of the apparatus is therefore of the greatest importance. The current meter is moved along a channel at a fixed speed which must be determined as accurately as possible at the same time that the speed of rotation is measured. This results in the plotting on a graph of a number of experimental points through which a continuous rating curve is to be drawn. The mathematical interpretation of this curve has led to empirical formulae which vary in accuracy. The author discusses several of these formulae in relation to the results obtained in his own tests which were made at the Hydraulics Laboratory of the Institute of Technology in Haifa, Israel. The tests were made with Watts cup-meters and small Ott propeller-meters as well as with locally made meters of a similar type. (S. Irmay, *La Houille Blanche*, Vol. 9, No. 4, July-August 1954, p 461, 5 pp., 4 ff.)

First 345-kV Line in U.S.

The first 90-mile section of this new line, which will carry about 320,000 kW from McNary dam to the Portland-Vancouver area, is being strung under 6,000 lb. tension in order to keep the conductor surface smooth, and reduce to tolerable limits corona loss and radio influence. Every care is therefore taken that the conductors do not touch the ground at any time. Pulling in is done by tractor, the three cables being pulled simultaneously. The average span length of 1,150 ft. reduces the chances of conductors sagging to the ground, but to be on the safe side in this respect one crew travels along with the conductor where it is gripped by the pulling cable, and where necessary planks are placed on any high ground under the conductors. Line construction begins with the placing of tower footings; then steel is conveyed to the tower sites and assembled into sections, which are finally raised by a mobile crane with a 115 ft. boom, and bolted into place. The stringing crews, who follow the tower erectors, receive the conductors in lengths of about 4,400 ft. on 42 in. steel reels. (*Electrical World*, Vol. 142, No. 9, 13.9.1954, p. 30, 3 pp., 7 ff.)

CLASSIFIED ADVERTISEMENTS

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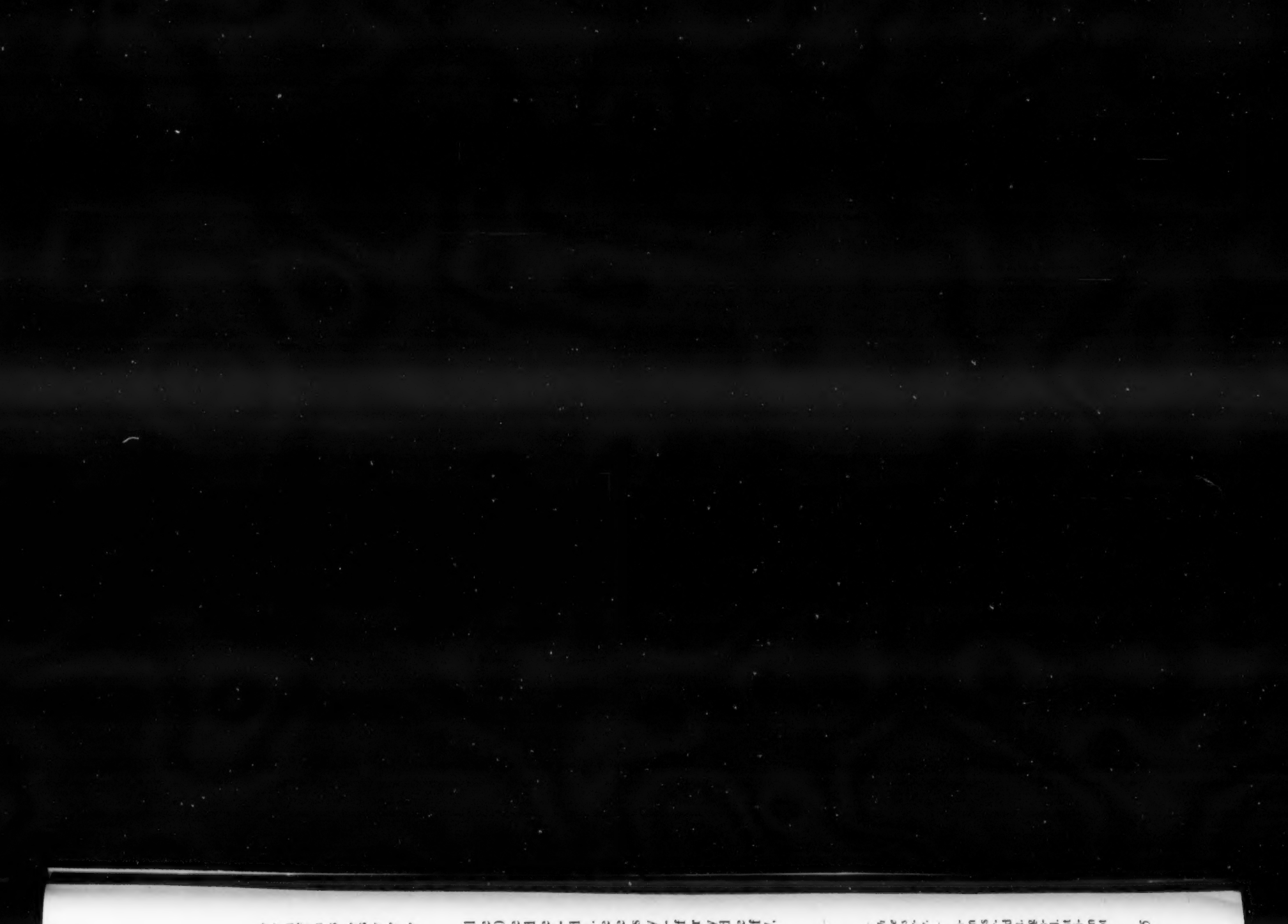
CONSULTING ENGINEERS in Westminster invite applications for engineering and drawing office staff for work on hydro-electric power stations. Applications for positions as assistant and junior engineers should have served an engineering apprenticeship with subsequent design, contract or field experience on water turbines, alternators or mechanical plant. Some electrical experience is also desirable. An engineering degree with associate or graduate membership of the Institution of Mechanical Engineers or its equivalent is essential. Draftsmen should have good experience on design and layout of heavy plant. Salaries will depend on experience and qualifications. Applications should reach Kennedy & Donkin (Reference H H), 12, Caxton Street, Westminster, S.W.1. not later than 24th March, 1955.